MILITARY SCIENCE
TO-DAY

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MILITARY SCIENCE TO-DAY

BY

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FOREWORD

THIS is a war of mechanism and applied science. Its outstanding features are intense mobility and concentration of fire power. The days of massed infantry attack seem to be waning: the machine has taken over many of the duties, and, it is to be hoped, the sacrifices of the man.

It is quite obvious that if the student of warfare to-day—and who, alas, is not?—is to achieve intelligent appreciation of the military problems of the present conflict, he must go for his information to a reliable, authoritative, and, above all, intelligible source. That is why I welcome, on behalf of innumerable readers, the timely appearance of *Military Science To-day*.

I have been privileged to study the book before publication. Having already read the author's *Science and Mechanization in Land Warfare*, I was confident that within the pages of the present volume I should find a clear, concise, and readable treatment of an intricate subject. My expectations were more than realized, and I can unreservedly recommend *Military Science To-day* to the reading public, especially those members thereof (and their name is legion) who find themselves leaders of men in the new and strange type of warfare into which Fate has plunged us.

IAN HAY

PREFACE

MUCH of this book was written before the outbreak of a struggle which is to settle whether the laws of civilization or those of the jungle are to survive, and the question arose whether to let it appear in the early days of what may be a long war.

It was Alfred Tennyson who wrote with much truth,

> Science moves but slowly, slowly,
> Creeping on from point to point;

but it is well known that military science moves more quickly in time of war, when the whole resources of the contesting nations are strained in their efforts to achieve new discoveries. Yet it does not seem that many far-reaching and unexpected surprises in the realm of science and technique are likely in the present war, least of all as far as Germany is concerned. Her two most successful innovations in the war of 1914–18 were chemical warfare and the submarine campaign, and these were both admittedly in flagrant disregard of those rules of war which she herself had solemnly undertaken to observe. The long-range shelling of Paris and of other cities was indeed a surprise, but, typically enough, it was a case of a careful and painstaking development and in no way a new discovery. Since then many of Germany's finest scientists have found shelter in Britain and France, whence Hitler has vainly appealed for their return. There is nothing more heartening than the number of decent and highly qualified Germans in this country who are doing their utmost to secure the downfall of Nazidom; further, the despair with which professors in German universities regard their new pupils is well known; these are chosen for their physique and their blind trust in Nazi principles and little or no regard is paid to intellectual qualities.

The writer has confined himself to a short account of the development of various branches of military activity in which scientific principles are involved. It was necessary to include a chapter on tactics, because tactics treats of the methods used by the soldier, and the first principle of tactics is co-operation. Without regard for tactics it is impossible to put the various applications of military science in their right perspective.

The various subjects have been treated mainly from the soldier's point of view, and little has been said from the airman's standpoint, though the vital and growing importance of air forces in warfare is fully appreciated.

For obvious reasons statistical details of weapons and equipment have had to be excluded, and any expression of opinion is merely that of the writer who was called up on mobilization for service with the Royal Engineers.

Finally, a word of thanks is above all due to the Director of Public Relations at the War Office, whose department provided most of the photographs that are produced in this book.

War is honourable
In those who do their native rights maintain,
In those whose swords an iron barrier are
Between the lawless spoiler and the weak.
(JOANNA BAILLIE)

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CHAPTER I

SCIENCE AND WAR IN HISTORY

EVER since the earliest dawn of scientific discovery science has been closely linked with warfare—in fact it is roughly true that the greatest advances in science and engineering have been due to military requirements. Man's first contact with nature arose from the need of getting food and this often involved fighting. The primitive craftsman was concerned firstly with the demand for tools and then with the demand for weapons. The Babylonians and the Egyptians developed machines and, as will be shown later, Babylonian fortification reached a high pitch of development. The Greeks borrowed much from Babylonian and Egyptian sources, and their philosophers, though remaining aloof from any kind of experimental practice, showed a degree of curiosity which laid the foundations of scientific thought. Plato himself regarded the scientist as mainly of value for his military worth, and the following quotation from his writings (*Republic*, book vii) is illuminating:

> 'for in camping, in occupying positions, in closing up and deploying troops, and in executing the various manœuvres of an army, it will make all the difference to a soldier whether he is a good geometrician or not.'

Men of distinction throughout the ages have regarded military service as a privilege of which they were proud. Aeschylus recorded in his epitaph that he had fought at Marathon, with no word of the four hundred plays that he had left; de Vigny was the richer as a poet for his life as a soldier.

In the Greek colonies clustered around the Mediterranean the application of science to warfare was much developed. Archimedes (257–212 B.C.) performed wonders in the defence of Syracuse against the Romans, and by his optical arrangements which set fire to the Roman fleet, and by his artillery and engines of war, he delayed the inevitable end in which his own life was to be lost. He can claim to be the father of military engineering. Archimedes himself set no value on the ingenious mechanical contrivances which made him famous, regarding them as beneath the dignity of pure science. He was reluctant to leave any written record about them. The engines of war which he devised for Hiero, King of Syracuse, almost terrified the Romans and protracted the siege for three years. It is to the credit of Marcellus, the Roman general, that he had given strict orders to spare the house and person of the sage, but in the general massacre that followed the fall of the city, Archimedes, while engaged in drawing a mathematical figure on the sand, was run through the body by a Roman soldier.

In the Renaissance it was the urge for improvements in artillery that caused dynamics in its modern sense to originate. Leonardo da Vinci and Galileo, the two outstanding scientists of the age, were both closely concerned with military affairs. The former owed his appointment on the staff of the Duke of Milan to his own knowledge of military matters. In his letter to the Duke, after claiming secret knowledge of means of making military bridges, scaling-ladders, light cannon and mortars, engines of fire, catapults, ships that were both gun-proof and fireproof, powders and inflammables, as well as the possession of an intimate knowledge of military mining and the building of canals, he commends himself 'in all humility' for employment with the Duke! Needless to say he obtained the post.

A characteristic feature of the Italian Renaissance was the extreme versatility shown by some of its leading men. Leonardo da Vinci is one example, and so is Michelangelo, who is to be remembered not only for his statues and frescoes but as the man whose skill in fortification defended Florence during a famous siege.

It is certain that the military urge was responsible for almost all the improvements in transportation—it is said with a good deal of truth that the state of civilization of a country can be gauged by its communications, and the Roman roads, which were so superior to anything that existed in this country until the 18th century, were certainly due to their military system, and the need of rapidly reinforcing any distant garrison. The earliest vehicle was undoubtedly the war chariot used by the Syrians, the Assyrians, and the Egyptians, and well described by Homer. Alexander, on the other hand, found that some of his greatest difficulties were due to the use by the enemy of battle-elephants, and they were also used by the Carthaginians against the Romans.

Much of the improvement in metallurgy in the Middle Ages was due to the need of superior equipment, both offensive and defensive, for the mounted warrior encased in complete mail, and riding a horse that was also protected. The knight in armour dominated the battlefields of Europe for a thousand years—no infantryman could stand up to him in open fight until new missile weapons were introduced, first the long bow and then the early musket.

It is worth noting that the greatest English scientists, Newton and Faraday for example, were little interested in the military application of science, although the discovery of the steam-engine in this country was to do much to revolutionize warfare.

In France it was far otherwise, and in the South Kensington Museum can be seen a model of a steam-engine invented by Cugnot in 1763 and intended to transport guns and military stores. It is a three-wheeled vehicle, the central wheel being actuated by the piston-rods of its two cylinders. Its main weakness was that its boiler was far too small, besides being made of cast iron. Its maximum speed was 2½ m.p.h. When tried in the streets of Paris it overturned and exploded while cornering and it was condemned as dangerous.

Lavoisier, the father of modern chemistry, was the head of the 'Régie des Poudres' at the French arsenal. It was only in the French artillery schools that science could be effectively learnt, and Napoleon was the first soldier of outstanding merit to profit by a scientific education. It is Descartes, great soldier as well as mathematician and philosopher, whose spirit, reigning in the two great military schools of St. Cyr and the École Polytechnique, gives the

French soldier, by reason of his profound training in mathematics, his peculiarly scientific outlook.

It was the large-scale production of steel, combined with the improvements in locomotion, that changed the whole technique of warfare. Bessemer's researches on steel were mainly the result of the invention of the rifled cannon in 1854 and the resulting need of a material stronger and harder than wrought iron. It was during the long peace of the nineteenth century that those scientific developments were produced that were to revolutionize warfare and to enable the movement of millions of men to be controlled; at the same time improvements in food-preserving and storage and in medical science were to enable the horde armies of the War of 1914–18 to be sustained. But even in that struggle the importance of the scientist other than the engineer was at first but dimly recognized. When, for example, a leading physicist first offered to organize a meteorological service for the British Army, he was curtly informed that the British soldier fought in all weathers!

Nevertheless, as the war went on, the importance of scientific research in many subjects, and particularly in chemistry and aeronautics, was abundantly recognized on all sides, and the formation of the Department of Scientific and Industrial Research was largely due to the need for military preparation in peace time. It is now fully recognized that under modern conditions war is no longer fought by the man in uniform alone but by the whole industrial strength of a nation, whose success in war depends largely on its industrial efficiency. Up-to-date methods are essential and the importance of research can hardly be over-estimated. An excellent example of its value is the way Germany has utilized nitrogen from the air for fertilizers and explosives, and is making much of her petrol from low-grade coal, much of her cloth from wood, and much of her rubber (buna) from chemicals. It is not unlikely that artificial and synthetic foods may be produced for use in this country in an emergency when supplies from overseas may be restricted by enemy activity.

The Germans were the first to attach value to the work of the theoretical scientist at a time when business men both in this country and America were inclined to belittle its worth. It was in Germany that the full importance of science in war preparation was first realized, and the German Army of 1914 alone had a really effective scientific training. This is not to suggest that its corps of officers was scientifically inclined, but their government was progressive enough to encourage scientific development and scientific teaching. The major discovery of the 1914–18 period, the Haber process for the fixation of nitrogen in explosives and fertilizers, was a German discovery which the allied blockade rendered of first-rate military importance. Institutions like the Kaiser Wilhelm Gesellschaft did much to encourage research, most of which was directed towards military purposes. Even after the war, when resources and facilities were so much reduced, German science continued to flourish and was encouraged in every respect by the Weimar Republic. The name of Einstein is, of course, associated with this period, and it is symptomatic of the Nazi outlook on life that this man should be hounded out of a country of which he was such an ornament. In no country at the present time is the usefulness of a discovery questioned because no immediate and practical value is shown. Was it not Faraday who, asked by a woman what was the use of his newly produced dynamo, gave as his answer, 'What is the use of a new-born baby?'

The three industries that have been stimulated most by research are the heavy metal industry, the chemical industry, and the aircraft industry, and in each it is difficult to separate the military from the civil side. In aeroplane production military aviation is overwhelmingly more important than civil aviation. Even before the rearmament boom nearly four-fifths of the aeroplane work in Great Britain was for military purposes; but Diesel development for aircraft has been more developed in other countries than in Great Britain. There can be no possibility of a disabling 'death-ray' in a machine with no coil or magneto. The aircraft industry has, moreover, stimulated largely the production of and research in light alloys, and the material of which Britain's aircraft are made is undoubtedly much superior to that used by Germany, largely owing to our more careful methods, greater buying power, and command of rare metals so essential for alloy purposes. Much metallurgical research is also being carried out to find harder and tougher materials to resist bullets and other projectiles. Aircraft fuels have also been a subject of research, especially 'anti-knock' petrols. For high-altitude flying a special two-stage blower is required, and with the necessary degree of supercharge a high mixture temperature is unavoidable. This tends to promote detonation, and the fuel must have a high 'anti-knock' value. The motorist who is dissatisfied with 'Pool' petrol should realize that the more volatile constituents are wanted for the R.A.F.

The military urge has also been paramount in aerodynamic research—stratosphere flight is of special interest to military aviation, as the anti-aircraft gun disappears altogether from the picture. Locomotion in the stratosphere presents many difficulties, but also offers many intriguing possibilities, and it opens up the likelihood of largely increased aircraft speed. For various reasons it is fairly certain that the maximum attainable speed under self-propelled conditions will be that of sound in air, i.e. 750 m.p.h. Rocket propulsion is also being tried, not only for the exploration of the upper atmosphere, but also with a possible view to navigation. Progress has been slow and the suggested solution of a series of step-rockets is not too promising. Furthermore, the technicians of many countries are developing rockets as a possible replacement for anti-aircraft guns. Up to a certain point the farther a rocket goes the faster it travels, whereas a shell loses speed from the time it leaves the gun. This feature is most important in anti-aircraft action when a moving target is being engaged. The steering of rockets by radio is still in its infancy, but developments are certain, and it is said that a long-range rocket has been developed which can travel 100 miles loaded with 50 lb. of explosive.

In engineering, research tends more towards the improvement of what already exists than to the completely new discovery. Efficiencies of prime-movers are being constantly increased by such discoveries as the Still engine, and the aeroplane engine is efficient to a degree that would have been regarded as impossible even twenty years ago.

The spectroscope is now in harness in the service of the engineer as well as of the scientist. With it the engineer can look through a window of fused quartz into the cylinder of an engine in operation. In Sheffield a complete analysis of samples of cartridge brass which would require a week to make chemically can be made by the spectroscope in less than three hours. A whole trainload of pig-iron can be thoroughly tested in a short space of time without unloading.

In the chemical industry the primary ingredients for explosives are nitric and sulphuric acid, coal tar derivatives, and various cellulose products, and these have all many peace-time uses. The same applies to chemicals that could be used for war gases, and for these the basic materials are coal, salt, sulphur, and air, all of which are peace-time essentials. It is a very slight chemical step from aniline dye to diphenyl-chlorarsine, an important war gas, or from nitric acid to chloropicrin. Modern progress in biological research has reached a stage when artificial foods have become a possibility, though not a gastronomic luxury, and this research has been stimulated by the urge for self-sufficiency, which has been developed to a remarkable extent by Nazidom.

Air-raid defences have led to a wide range of experiments in all sorts of directions. Scientists are attempting to perfect smoke-screen black-outs for both military and civil objectives, thus enabling lights to be kept burning for vital industrial purposes. A heavy brown smoke which clings close to roof-tops and takes a considerable time to disperse would seem quite a possibility, the density and weight of the smoke being regulated according to the prevailing atmospheric pressure and wind strength. This may provide a solution to the problem of concealing river lines, which are most useful to hostile airmen in night raids. The creation of a respectable degree of illumination invisible from the air is also in process of development.

Discoveries of military importance are co-ordinated, as far as the Army is concerned, by a body known as the R.E. and Signals Board.

From these few examples of the application of science to war objectives, it can be seen how important it is for the scientist to face up to military problems and for all facilities to be provided him in his task. We are a peaceful nation, with the traditions firmly embedded that our national security and the protection of our far-flung Empire can be left to our Navy and to a small professional army. Ostrich-like we buried our heads in the sand for many years, and refused to recognise the menace that was arising in Central Europe to free institutions, and to freedom of thought.

It is to the young man trained under free conditions that we must look for the elasticity that is needed in the leaders of a mechanical age. Methods of encouraging toughness in labour camps may enable the Nazi manhood to put up with hardships, but those methods also put a premium on imagination, and the sealed-pattern mind has little place in the scientific warfare of to-day. History itself makes plain the murderous consequences which a mistaken judgement in the science of war always involves.

CHAPTER II

MODERN TACTICAL IDEAS

'It is not easy to determine whether industrial progress, improved organization, the spread of education, or mechanical inventions, have wrought the greatest change in the military art.

'War is first and foremost a matter of movement; and as such it has been considerably affected by the multiplication of good roads and the introduction of steam transport. In the second place, war is a matter of supply, and the large area of cultivation and the possibility of foodstuffs being poured from one continent to another, have done much to lighten the difficulties of a campaign. In the third place, war is a matter of destruction; and while the weapons of armies have become more perfect and more durable, the modern substitutes for gunpowder have added largely to their destructive capacity. Fourthly, war is not merely a blind struggle between mobs of individuals, without guidance or coherence, but a conflict of well-organized masses, moving with a view to intelligent co-operation, acting under the impulse of a single will and directed against a definite objective. Means of intercommunication, therefore, as well as methods of observation, are of great importance; and with the telegraph, the telephone, visual signalling and balloons, the armies of today are at a great advantage compared with those in the middle of the nineteenth century, and military organization has become a science, most carefully studied both by statesmen and soldiers.'

These words are not new; they were written nearly half a century ago in the forefront of Henderson's classic writing, *The Science of War*, every word of which is still worthy of perusal by the thoughtful soldier of to-day. Change steam-engine to internal-combustion engine, balloon to aircraft, and the quotation is fully up to date.

The leaders of the World War of 1914–18 were dominated by the theory of the human mass, and their main efforts were concentrated on the bringing of superior numbers together at the decisive time and at the decisive place. Napoleon's dictum that it is *the* man that counts, not the men, was forgotten, and as numbers on both sides were in the main not unequal, the long trench deadlock followed.

It was the Germans who applied new infiltration methods in their successful break-through in 1918, but, lacking tanks, they were unable to exploit success, and the break merely became a bulge with a larger garrison needed for the longer line. It was their losses in these attacks, combined with the slow but certain pressure of sea power, the arrival of large American reinforcements, and the exploitation of success by the tanks, that was to enable the Allies to overcome the enemy will. Wars are lost only when one side believes itself to be defeated, and it was then and only then that the German leaders consented to Armistice conditions, whereby all power of further resistance was destroyed.

The changes in the structure of all armies during the war were mainly additions, and the essentials remained unaltered. Infantry was at the end as at the beginning the backbone of them all, and our battalions that followed after the retreating Germans for the long 'watch on the Rhine' were similar in composition to those that deployed on 22nd August 1914 along the Mons canal. Each consisted of about 1,000 bayonets with a long string of horse transport for its support, the only essential difference being that the 1918 veterans counted on a large number of automatic rifles to increase their fire power in place of the two machine guns which had come to be regarded for some decades as the correct complement for a battalion. What was added was the means of supporting the infantry—trench mortars, far more machine guns, more and heavier artillery—while such ancillary aid as could be given by sappers, signallers, and the like was much increased. The one new invention was the tank, and this also was first intended solely as a means of assisting the infantry to penetrate the belts of wire and other obstacles and to get to close quarters with the enemy, without the crippling losses that would otherwise be sustained. Cavalry remained unchanged, and though of vital importance in the Eastern campaigns, it was regarded by many on the Western Front in the same light as the vermiform appendix—something unnecessary yet still existing.

It was in the last year of the war that an entirely new species of tank began to be produced, the intention being that it should fulfil a purpose that had hitherto been reserved for cavalry—to achieve surprise and to exploit success. These tanks were intended for use after the heavier machines had reached the hostile lines, and they were to be faster and altogether more mobile than any tank hitherto constructed.

The Armistice arrived before the type could be fully tested in action, but after the war and with the restricted means that peace conditions allow, this conception was further developed, and in 1923 the new Vickers medium tank first saw the light of day (see Plate 2). With a maximum speed of about 20 m.p.h., fairly good cross-country capacity, and radius of action reasonably high, it was at its birth far ahead of any other machine. It is a tribute to the touching faith of the British in the peaceful intentions of our neighbours that this tank should have survived—fifteen years later—as the only medium tank in the British Army, whose war-time lead in tank-warfare had by then been completely lost.

Some further details of the armoured fighting vehicles in the Royal Armoured Corps will be given in a subsequent chapter, but with the more realistic outlook after the German seizure of Czechoslovakia the situation began to improve with the rearmament campaign, though conditions gave no chance for their use when Hitler decided that the time was ripe for the rape of Poland.

In the British Army in the years following the Armistice and the Treaty of Versailles, experiment after experiment was tried, and for many years the infantry organization included machine-gun companies and rifle companies, and after that the experiment was made of machine-gun battalions and rifle battalions. The former with their Vickers machine guns still exist, but on a reduced scale, and with the arrival of a really satisfactory light machine gun called the Bren gun (Plate 3)—the name was derived by the combination of the first two letters of the unpronounceable name of Brno where this gun was first made, and the first two letters of Enfield where the British model was fabricated—the rifle became merely the personal protective weapon of the individual soldier. After many vicissitudes the organization of the infantry battalion has now been stabilized, and is based on the following considerations:—

1. The desirability of possessing an element of mobile fire-power and protection by the introduction of armoured carriers mounting Bren guns.
2. The possibility of reducing the personnel in the battalion in view of the increased fire-power of the Bren gun and the increased mobility obtained by the mechanization of battalion transport.
3. The need for a close support weapon immediately available within the platoon leading to the introduction of a 2-in. light mortar.
4. The need for an increased number of pioneer personnel under modern conditions.

Each platoon now has a truck which carries the greater part of the soldier's equipment, and which can be used in special circumstances for his personal conveyance.

The new organization of the infantry provides for a hard-hitting and flexible force capable of playing an effective part under the very varied conditions that the security of the British Empire involves. For fire-power the main basis is the Bren gun, and each battalion carries a very large number of these weapons which are equally suitable for accurate fire by day, for firing on fixed lines by night, or for anti-aircraft defence. The rifle is still of importance but is relegated to a comparatively subsidiary role. Other weapons in the possession of the infantry include the anti-tank rifle, two types of mortars, the hand grenade, and the bayonet. Medium machine guns (Plate 4) are reserved for the special machine-gun battalions, which are very mobile units. The anti-tank rifle is a great contrast to the German weapon for that purpose in the 1914–18 war, of which it was said that the German soldier would face almost anything in preference to the task of loosing it off. The anti-tank rifle is not a specialist weapon and all ranks are trained in its use.

Machine guns have their limitations as they are useless against troops in trenches and in folds of the ground; and for searching dead ground as well as for producing smoke the mortar is unrivalled (Figs. 1 and 2). The 2-in. mortar (Plate 4) is small, easy to conceal, and is a weapon of especial use in the attack as it is a good smoke-producing weapon.

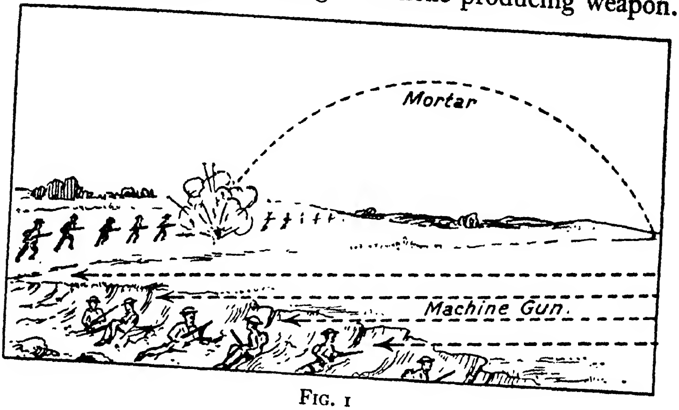

FIG. 1

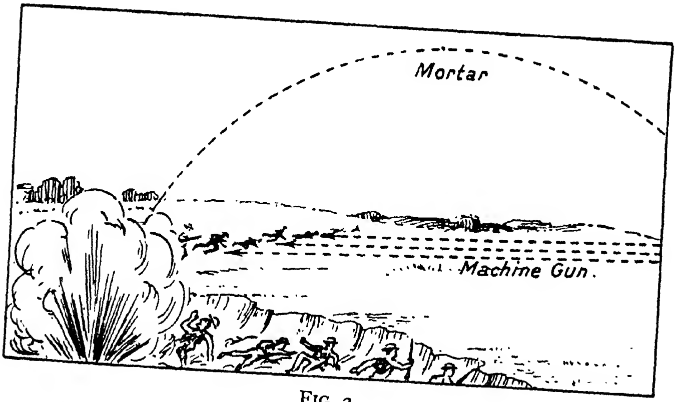

FIG. 2

But it is important to remember that smoke is a two-edged weapon, as its indiscriminate use may cause our own troops to lose direction; it may easily disorganize arrangements for artillery and air observation and for visual signalling. Moreover, its effectiveness depends on climate and weather conditions. The larger mortar is a far more formidable affair with longer range and larger killing radius. It provides a useful reserve of fire-power in the hands of the battalion commander and gives quick close support on ground not covered by artillery observation. The size of its bomb precludes its use on a large scale under very mobile conditions.

Another feature of the new infantry battalion is the provision of pioneers in response to the ever-increasing demand for field-engineering under modern conditions, particularly in connexion with anti-tank and anti-gas defence. Old soldiers will remember the pioneer section of bearded men marching with their picks and shovels at the head of the Victorian infantry battalion, and it is interesting that history has repeated itself in this respect, though the beards are now missing. These infantry pioneers include a percentage of tradesmen, and they are trained in engineering duties over and above those that the ordinary infantry soldier can be expected to carry out. They are specially skilled in anti-gas duties, field defences, the construction of obstacles, and the provision of simple camp services.

Perhaps the most interesting feature in the infantry is the armoured carrier (Plate 5) a platoon of which belongs to each battalion. These caterpillar vehicles are not tanks, but they supply the battalion commander with a reserve of mobile fire-power, capable of traversing rough ground and bullet-swept zones at a high speed. They resist rifle bullets at all ranges, and are equally useful in attack and defence until the latter has crystallized into mere position warfare.

Concealment is an important feature of the modern army, and each Bren gun and anti-tank rifle is supplied with what is termed a spider and net, intended as a cloak of invisibility if properly employed. The soldier must realise that unless concealment is well practised during training, his chances of survival on a modern battlefield are so slight that his presence will merely serve to encumber the work of the medical and burial services.

Infantry tactics, with all these new weapons comprehensively organized, differ widely from the simple conceptions of a few years ago, though the same simple principles remain. Mobility, moreover, has been so much attained that it would seem wise to complete it (as has been done so widely in other arms). This would involve the provision of trucks for the men as well as their equipment, and would require an extensive addition to the already numerous vehicles in the battalion. The motor transport companies of the R.A.S.C. in reserve for this purpose could, however, be abolished. Even then it is wrong to imagine that the soldier would no longer have to do any marching; in the presence of the enemy it is often quite impossible for the trucks to be right forward and the equipment has then to be carried.

In attack in particular, good co-operation with other units and other arms is all important. Above all, plans must be sound and simple, with a careful use of ground. Smoke is often required in daylight attacks, and the new smoke projectors are effective with a minimum of 'pillaring'.* The platoon is the unit upon which infantry tactics are based, and infantry soldiers are encouraged to fight their way forward with their own fire-power, using infiltration methods.

In defence the new infantry battalion, with its extensive fire-power, is particularly formidable. The principle of defence in depth with mutual support of defended localities is usually employed. In foremost sections the Bren guns are given arcs of fire covering the approach to their positions, whereas guns protected from the front are given arcs of fire and fixed lines, arranged so that ground is adequately covered, preferably by flanking fire. As each platoon has its equipment in its own truck, it digs itself in almost automatically, and there is no delay such as was unavoidable when picks and shovels had to be sent up from battalion head-quarters.

For the siting of forward defensive localities there is usually a good deal of choice. There are a number of conflicting factors and a compromise is then the result. Anti-tank guns are most effective if sited on rear slopes so that the guns shoot up the tanks as they come over the crest. The need for observation, particularly by artillery and machine gunners, often involves the siting of foremost defended localities well in advance of observation areas, as otherwise observation may be prevented by a local enemy

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* 'Pillaring' is the term used for the tendency of a smoke-cloud to rise in the air.

success. On the other hand, concealment is of vital importance, and this conflicts with the protection of high ground which may involve exposed positions for the infantry. The ideal is for the infantry to be concealed on minor slopes and in rough ground well in advance of commanding ground in the rear which is then available for observation. It is by no means always that conditions suit for this, and it is important that junior officers should have the necessary tactical knowledge to enable them to make the best of the ground. Facilities for observation, well-concealed positions, covered approaches in rear enabling counter-attack troops and supplies to be filtered forward, areas defended by natural tank obstacles, all these are of vital importance in defence, and the young leader must know how to make the most of the ground at his disposal and to improve its defensive possibilities by artificial means.

The new infantry organization is far more suited to modern conditions, but it calls for high qualities of skill and initiative. The conception is of a swarm of skilled individual fighters, and the parade-ground old time soldier is altogether out of place on the modern battle-field. Control has now passed to junior officers and N.C.O.s, and the infantry soldier can claim that his job, if properly performed, calls for higher skill than that of the supporting arms. Discipline is of greater importance than ever, but it must exist in a form that neither warps self-reliance nor initiative. The infantry soldier of to-day is taught to think for himself. Figs. 1 and 2 (p. 25) are illustrations of the pictorial methods whereby the army teaches the soldier the advantages and disadvantages of the various weapons that he is required to use.

But in order to understand how the new-model mechanized army works, it is necessary to have some conception of the nature of the modern battle-field. The picture must not conjure up any cut and dried arrangement, least of all for the British soldier, who may be required to face all sorts of circumstances ranging from garrison duty at Hong Kong to mechanized mobility on the Egypt–Libyan frontier. It was the Duke of Wellington who remarked that you can no more describe a battle than you can describe a ballroom, but for a continental force advancing at the initial stage of a war on an open frontier, three succeeding waves are to be pictured, i.e.

1. Air bombardment on a scale far exceeding anything hitherto attempted.
2. Mobile armoured troops, including heavy and medium tanks, intended to penetrate any initial defensive screen.
3. Normal troops supported by masses of artillery to occupy and to strengthen all ground won; their art will be to hammer away at all weak spots in order to penetrate farther. This has its limitations, as infantry fire never made a determined enemy go—it just keeps him down, and the only way to make him go is to get round him. This is of course impossible in the fortification of the Maginot line type, and what cannot be at present envisaged is the likelihood of success in any reasonable period of time against such formidable works, if held by adequate garrisons of unshaken and well-equipped troops.

In their advance on Poland in the first half of September 1939 the Germans made full use of their mechanized mobility both in the air and on the ground, and in this they were favoured by the fine and dry weather. Their airmen made a special and successful effort to put the Polish aerodromes out of action with their far superior air organization. Next, chaser machines and armoured troops attacked in front of the infantry. The task of the armoured formations was to get through the hostile lines quickly, to destroy the Polish artillery and also their staffs, and thus to break up all opposition. In view of the small number of Polish prisoners reported captured in the early stages, it is more than likely that the German tanks, surrounded by disorganized Polish infantry, simply mowed down anything showing opposition to their advance. The fact that armoured troops have no facilities for providing guards for prisoners adds another ghastly possibility to modern warfare. The Polish soldier is a courageous fighter, but with little to fight with except rifles, troops stood no chance against tanks and aeroplanes that dived down and attacked with machine guns any formed parties of troops. It would seem, moreover, that a further cause of their misfortunes was the complete and early collapse of wireless communication. Many Polish independent formations had no idea of the situation of their G.H.Q. which was, however, always known to their enemy, thanks to the superb system of German espionage. Both their military head-quarters and the seat of government were consistently bombed.

The British Army has many possible functions, and in major war is mainly required to assist an ally in land operations, so that any specified tactical doctrine is not so necessary; but a good deal has been written and spoken by a school of thought headed by a military correspondent of *The Times*, emphasizing the advantage of the defence, and the danger of the alleged continental predisposition for the offensive. There is much cogency in this argument, and defence is now technically superior as far as army operations in restricted terrain are concerned, though certainly not in the air. But defence cannot achieve victory, and the value of the offensive as well as of surprise is recognized in every game that we play.

The German field-service regulations make their tactical doctrine crystal clear. The aggressive spirit—boldness, attack, exploitation, character—epitomizes their basic doctrine of battle. 'In war, character outweighs intellect', 'the worth of man is the decisive factor'—this is the refrain that runs through their regulations. The qualities that are most wanted by the German are those of the redoubtable Percy in 'Chevy Chase':

> For Witherington needs must I wail
> As one in doleful dumps,
> For when his legs were smitten off
> He fought upon his stumps.

In attack great care is taken that artillery support should be adequate. Their artillery material is good whereas much of their other equipment is definitely of poor quality. A methodical advance is encouraged with a good deal of trouble in locating what is in front, finding the weakness, and then exploiting it. The German soldier is taught that even without tank support he can advance and defeat the enemy. Ruthlessness is also encouraged, with scant regard for the principles of civilized warfare.

Both in defence and delaying action the German strives for mobility, taking up shocks by a sequence of buffers. There is no rigidity. In general, the German commander rests his case to-day upon a thoroughly trained and numerous personnel, a strong mobile reconnaissance, a strong anti-tank defence, and an aggressive and bold leadership. The French tactical doctrine is more realistic in its appreciation of the advantage of an active defence. In their army, as in ours, there was a static period with the division little changed from the war-time pattern, and with horsed transport. But the recent years have seen changes much on the lines of ours, with armoured carriers in the infantry and tractor-drawn artillery.

It is reported in the press that many of the French cavalry regiments are mechanized very much on the lines of our own, with the armoured car a more considerable feature. These carry a gun and a machine gun, and are manned by four men. The two drivers, with separate engines fore and aft and separate control, are assisted by a gunner and a wireless operator. The gunner occupies a revolving turret, and has the well-tried 37-millimetre gun and a machine gun, operated together or separately. Two-way wireless is installed, enabling control to be maintained from regimental head-quarters, or by a liaison officer acting as observer in a co-operation machine overhead. Another feature is the motor-cycle and side-car company, in which machines the driver and gunner are trained to change places on the move. The infantry regiments have an anti-tank platoon equipped with the 37-millimetre gun on mobile armoured vehicles resembling motor cycles. These guns are fed with single cartridges of explosive, or with solid, shells, and can fire at the rate of about twenty rounds a minute.

The French also appreciate the need of a considerable number of professional soldiers over and above their conscript intake. Both in its degree of training and in the experience and efficiency of its corps of officers, their army takes second place to none. As their tactics against the Siegfried *Stellung* have shown, they adopt cautious exploitation, nibbling first here then there, and encouraging hostile counter-attacks when a high toll of enemy lives can be taken.

It cannot be too widely understood that tactics are merely common sense, which has been cynically described as the rarest of all senses. The common-sense precepts which govern tactics, whether in the presence of an enemy or on other less vital occasions, are very similar to those that govern everyday life. It is undeniable that modern weapons have thrown increasing responsibility on junior commanders, and that success in battle depends largely on their efficiency. The essential qualities of leadership and fighting spirit are necessary, but unless properly applied they will fail to achieve the success they deserve.

The ordinary citizen, before undertaking any enterprise, sums up the pros and the cons of the matter, and often has to consider to what extent a rival may be capable of affecting his decision. Once having decided on his course of action he goes on with it, unless some quite unforeseen circumstances occur. But in war the time factor is always more urgent; information is both hard to obtain and unreliable, and other factors such as danger and exhaustion are often present. The conditions of war are so utterly unfamiliar to the average citizen that he finds some difficulty in applying those qualities of balance and common sense that he would certainly bring to bear under everyday circumstances. Moreover, in war there is always a chance of unforeseen incidents and obstacles to an extent far in excess of what is likely to be met with in everyday life: the enemy attacks in an unexpected place, a message goes astray, some key-man becomes a casualty, petrol runs out at a critical moment. It is this that makes war so difficult, and it is for this reason that the leader must have an almost instinctive knowledge of the right thing to do so that he leaves nothing to chance. When a boxer is in the ring he carries out some course of action almost instinctively, and it is fatal to lead or parry 'by numbers' as it were. Moreover, he must keep his guard up throughout and move quickly so as to achieve surprise. His hand, foot, and eye must be properly co-ordinated; and in exactly the same way all parts must work in combination in a fighting force. Furthermore, in spite of all that is said about the advantage of the defence, no boxer can achieve success, other than the occasional unexpected knock-out, unless he does his fair share of 'leading'.

The principles of war are easy enough to grasp, but no one can become a leader in the field by learning them from a book. But what is of value is the application of these principles in peace-time exercises, whether on sand-tables, in training exercises without troops, or simple tactical exercises in the field. One of the best ways of getting that instinctive grasp of tactical principles that is so necessary to the leader in war is by attempting to teach them to others.

In general, the junior leader who is given a task in the field has to take certain steps which he will ultimately have to carry out almost instinctively:

1. He must first make certain that he has thoroughly grasped what is required of him and that he has all the information that is wanted. The man is lost who goes off without knowing exactly what he wants to do, just because he doesn't want to appear stupid.
2. He must carefully study the map if he has one.
3. He must carefully reconnoitre the ground as far as time permits.
4. He must then decide on his plan, and this should be as simple as possible as it will then be more likely to succeed.
5. He must communicate his plan to his subordinates, and to do this properly the correct sequence of orders should be known.
6. He must place himself where he can best control his unit, always remembering that in a crisis personal example and leadership are the factors that count most.

In all tactical operations the proper use of ground is the decisive factor. In defence, for example, facilities for concealment are essential, natural cover being by far the best. Concealment is also more important than a long field of fire, while under modern conditions it is usually enemy armoured vehicles and aircraft that must receive special consideration.

Besides knowing the capacity and effect of the weapons under his control, a commander must have a close and intimate knowledge of his own subordinates. It is the personal factor that is all important, but it is far from necessary to be unduly familiar with subordinates to create that devotion and comradeship that is so essential if a leader is to be followed in moments of danger; nevertheless, the best results will not be achieved unless the subordinate realizes that his leader is a better or more experienced man than he is, and unless the leader can inspire respect and confidence. Furthermore the officer must not merely train and lead his men; he must *know* them as well, find out for himself their mental background, and get to learn something of their worries and of their thoughts. Sympathy and an understanding of human nature comes into this picture.

Thomas Atkins can go to war to-day confident not only in the justice of his cause but with the knowledge that his arms and equipment are the finest that money can buy. It is his task to make the world safe for all the peace-loving and freedom-loving nations, and he will carry out this task in a phrase that has become historic: 'Not without mercy, because God forbid that we should ever part company with that, but at any rate with zeal and not altogether without relish'.

CHAPTER III

MECHANIZATION AND SOME OF ITS PROBLEMS

THE mechanization of the Army is a subject with many ramifications, and it has effected changes in the Army which can only be compared to those in the Navy when sails were replaced by the steam-engine. As in the Navy, a good many of the 'old guard' resisted the changes, and even the more progressive-minded of the older generation inevitably find it difficult to face up to the enormous increase in the importance of the time factor, now that military movements of 100 and even 200 miles a day have replaced the traditional day's march of 20 miles, which had remained unchanged since warfare first began.

It is easy to criticize the slowness with which the British Army adopted the many mechanical means that were available—judgement after the event is never difficult. It is perfectly true that in the past, at any rate, the Britisher in general, and the British soldier in particular, used to find many more pleasant ways of employing his hours of work and leisure than in keeping abreast of the highly specialized world of science and engineering. But this is not the whole story. Any invention is bound to involve all sorts of practical snags, and in civil life the newly born idea gets all the aid necessary to enable it to overcome the many early weaknesses. There is no enemy doing his best to prevent its growth as is the case with the war-time military discovery.

In spite of the slowness with which the tank idea was developed and the many mistakes that were made, it is at least to our credit that the tank was essentially a British invention, and it can be rightly claimed as the greatest contribution towards the winning of the war of 1914–18. It was in the summer of 1916 that the first tank was in being, and its nature is well described in Major Sheppard's work on tanks:

> 'This Tank, Mk I, to give it the official title adopted originally for purpose of concealment and since become general, was a curious

affair with a contour rather like that of an ill-shaped diamond. The all-round tracks enabled it to cross over rough country and trenches; its great weight served to crush wire, guns, machine guns and men, and smash down trees and buildings and obstacles; its speed, slow as it was, was as fast as that of the infantryman it was designed to accompany and help; and the light guns and machine guns which formed its armament rendered it formidable to any foe, and its armour made it impenetrable to ordinary bullets. Elementary, clumsy, defective in many respects, it was yet a novel, terrifying and potent engine of war. Had we been content to wait until we had provided ourselves with a really large tank force, manned by well-trained personnel, with ample reserve of men and materials to back it up, a great and perhaps a decisive victory might have been won by its aid.'

Actually the result of the first operation was a disappointing failure, which was not surprising in view of the lack of preliminary preparation, and the piecemeal way in which the pioneer tanks were used.

It was the battle of Cambrai in November 1917 that proved conclusively the value of the tank. Originally intended as a mere raid on a large scale, nearly 400 tanks broke through the enemy lines at a point where they were not expected. Although lack of preparation for so successful an enterprise robbed the British Army of more than a tactical success, there was henceforth no doubt about the value of the tank as a means of gaining ground, and of breaking up the enemy without the appalling casualties that had hitherto seemed inevitable.

In 1918 the French introduced a new idea of their own, the Renault light tank, weighing a mere 6 tons and carrying a crew of ten, with one machine gun. This was more like the light tank of the future than any other, and these tanks did a good deal in the successful attacks that concluded the war, though the success of the British medium tanks on Germany's black day of 8th August 1918 was the outstanding tank success of the year.

As already described, the British medium tank of 1923 carried on the tradition that the French Renault light tank had started, and although it had many weaknesses, no other army had as good a medium tank at that period. Later on a much superior tank was produced, known as the 16-ton tank (Plate 5). It was outstandingly efficient, with its guns in separate turrets, and it was well armoured and much faster than the Vickers medium tank; but the disarmament conference intervened; it was assumed by the British, though by no one else, that the long looked-for millennium had arrived, and after having completed its trials and given every satisfaction, this tank was never issued. In spite of the muttering of thunder in the East, the British government kept complaisantly in its belief that the era of wars had ended, and although money was voted to keep the Army at its establishments, which were incidentally never maintained owing to poor recruitment, nothing was done till about 1936, by which time our former lead in tank design had been completely lost. However, it is worse than useless to bemoan the past, and a great deal has recently been done to overcome the leeway.

Modern doctrine in general suggests that, apart from such vehicles as the infantry Bren carriers and armoured cars, which, while ranking as armoured fighting vehicles, are certainly not tanks in the proper sense, there are three types of tank that are essential. Two of these types are intended for working with armoured mobile divisions, and can best be described as corresponding to the cruisers and mosquito-craft of a naval outpost force. The analogy suggests some heavy tanks to correspond to battleships, and these are required for action against fortified positions. In the present war the French have effectively used large numbers of heavy tanks weighing over 70 tons and with armoured protection against direct hits of light shells. The sapper is not to be envied who has to provide bridging facilities for such monsters! The smallest tank, corresponding to the torpedo-boat of the Navy, is the light tank (Plate 2). It is a machine of relatively light weight with a crew of three, fairly quick and well armoured, and it has been issued in large numbers to mechanized cavalry.

The next type is the medium tank that is replacing the old Vickers tank. This type is also supplemented by 'close support' tanks intended to assist in dealing with hostile anti-tank weapons. The feature of these tanks is that mortar fire is used and efficient smoke-producing arrangements are well developed.

Incorporated in the tank brigades are medium and light tanks whose role is usually independent, and whose mission will often be on flanks as well as in exploiting success. In defence their main purpose is counter-attack.

Quite apart from these tanks and with a totally different object, we now have the infantry tank—known as the 'I' tank. This tank is intended, as the name implies, for working with the infantry. The battalion organization that embraces this tank comprises lighter tanks as well. The 'I' tank is armed with a light gun as well as a machine gun. It is heavily armoured, but it is a good deal less speedy than the tanks of the independent tank brigades, and it is somewhat heavy. These tanks may be used in assisting the initial attack or kept in hand to maintain the momentum of the attack in the later phases. They may attack coaxially with the infantry or in a converging movement. Carrier platoons can be used in following tanks quickly and infiltrating behind enemy posts still holding out.

In defence, infantry tanks should be used for counter-attack purposes, being retained as an offensive reserve. Tanks of no category should be used dispersed. One school of thought holds with some cogency that the infantry tank is a retrograde step, and that our aim should be to give the infantryman the speed of the tank rather than to gear down the tank to the speed of the infantryman. It is held that by a more universal employment of the internal-combustion engine on the field of battle, the attack by foot-soldiers may be eliminated altogether. That this will be attained one day is hardly open to question, but whether it is feasible under present conditions must be considered as doubtful.

The greatest change in mechanization as far as armoured vehicles are concerned has come from the widespread change-over of cavalry from the horse to the tank. The mechanized cavalry regiment is equipped both with Bren carriers and with light tanks. The new light tank has many advantages and lacks many of the disadvantages of cavalry, though it cannot claim the saving grace of silence. Mechanized cavalry formations are ideal for wide flanking movements where surprise and speed offset their relative lack of armour, but they cannot search country with the thoroughness of which horsed cavalry is capable. The light tank is suitable for reconnaissance, and ably carries out the minor tactical action which its place in an armoured division involves. It is fast, has a good radius of action, and manœuvres well. It supplies a reasonably good viewpoint for an observer, who offers only a 'head and shoulder' target; it can open a 'spray' of automatic fire instantly in any direction, and its commander is in continuous radio-telephonic communication with his fellow tanks as well as with his squadron leader. The cavalry spirit, an eye for country, quick decisions, and above all a sound knowledge of tactical principles are more than ever wanted in its new setting.

As so many cavalry regiments were equipped with tanks it was evident that the bond between cavalry and the Royal Tank Corps was so close that something must be done to regularize the alliance. This has been achieved in the formation of the Royal Armoured Corps, which embraces all the mechanized regiments of cavalry and the battalions of the Royal Tank Corps. As it is difficult to conceive of a corps within a corps, the latter is now termed the Royal Tank Regiment. Men are enlisted with the Royal Armoured Corps as a whole and are liable to serve in any unit. Ultimately in peace there is to be a single recruit-training unit for the whole corps. Association rather than amalgamation is the keynote of the change, and the least possible disturbance to regimental tradition and feeling has thereby been caused.

Armoured cars have faded somewhat out of the picture in recent years owing to their small capacity for cross-country work and the vulnerability of their pneumatic tyres. The Lanchester six-wheeler is a useful vehicle with its machine gun and anti-tank gun coaxially mounted in its turret. It may be ideal for strategical reconnaissance, but the light tank serves adequately for this purpose and is far more useful for tactical purposes. Moreover, armoured cars can be extemporized more easily than other military vehicles after the outbreak of war.

It has been seen that progress in the latest machines as compared with their predecessors of the last war has been outstanding. Their speed has increased from about 10 to at least 30 m.p.h., their radius of action has risen from 15 miles to eight times this amount. Armament is on the whole less in weight of delivery but far more efficient. Modern tanks are far handier, and their springing and suspension has been vastly improved. At the same time it cannot be denied that anti-tank defence has shown no less striking an improvement, and this is in keeping with the general trend of military affairs in other directions.

Defence against tanks may be achieved by mine-fields, by obstacles, or by anti-tank weapons. The first two means concern the sapper and the third comes within the province of the gunner, and indeed of the Royal Tank Regiment, since the most effective enemy of the tank is the tank itself.

In mobile warfare the supply of mines seldom permits of mining large areas, and their employment must usually be effected in conjunction with anti-tank guns. In protracted defence it is possible to make use of mines that are large enough to destroy the tank itself, but under mobile conditions the most that can be achieved is to destroy its track. Some 4 lb. of high explosive is capable of achieving this, but the general tendency is for larger charges to be employed. In the contact mine the tank itself hits a striker which actuates a detonator and sets off the charge (Plate 19). Another type of mine is the electro-pneumatic mine, which is a more ambitious affair with a charge capable of damaging the tank itself. This mine is buried under the ground and a rubber tentacle is placed on the surface. A vehicle crossing the tentacle causes a flow of air which depresses a diaphragm, thus completing an electric circuit which actuates the detonator. This mine is intended for the protection of specific places of importance, head-quarters, railheads, &c.

The contact mine is far more widely used and a large number are carried in the field, their replenishment being on the same lines as that of the ammunition. Such mines can be placed on the surface of the ground or may be partially buried, but the former method is on the whole preferable. It takes longer to 'plant' a buried mine-field, and the effect of the mine is to some extent 'blanketed' by the earth. Such buried mines tend to be seen from the air, traces of the working-parties being also often conspicuous. Actually a tank in action, with its visor closed, does not easily see a mine-field in either case.

Soon after the end of the war of 1914–18 many experiments were carried out with magnetic mines constructed on the same lines as those that have been strewn over the shallower parts of the high seas by the German Navy in disregard of the rules of mine warfare. The principle employed is simple, control being effected by a magnetic needle which is deviated when a large mass of steel comes within a few feet of the mine. These tank mines were complicated, expensive, and uncertain in their action, and the experiments were therefore abandoned. Moreover, it is not difficult to create an electro-magnetic field by means of a relatively small current which would supply a tank (and also a ship) with a 'magnetic apron' around it, thereby causing the mine to be neutralized or detonated at a safe distance from the tank. The induction created by an electro-magnetic field is enormously larger than that due to the feeble permanent magnetism in the plates of a tank or of a ship.

The laying of anti-tank mines is normally undertaken by sapper personnel, who can lay them, and also remove them if necessary, with considerable rapidity. The most frequent use of the anti-tank mine will occur during withdrawals, and particularly in the blocking of roads when time does not permit of cratering. It must always be remembered that the charge merely anchors the tank and does not destroy it. The crew can usually fight in their vehicle until it is knocked out by some other means. They can also replace the tracks in an hour or two. The normal procedure adopted by a tank on discovering a block will be to work round it, destroy the defending troops, and then remove the block. It should therefore be sited so that it is come upon unexpectedly where deviation is awkward; and the protecting troops should, if possible, not be exposed to the direct fire of the tank which has detonated the mine.

If the mines are covered by small-arms fire alone with no anti-tank rifle and gun, a tank could be used as a shield and the mines be raked away from behind it. One of the advantages of burying the mine is that this procedure is made more difficult. Except in bare country and on road surfaces, anti-tank mines are not likely to be seen by tanks working with their visors closed, but mine-fields in open country are recognizable by aeroplanes flying fairly low. Even in fairly good cover the trampling of the vegetation may disclose the existence of a mine-field, but in sugar-beet and other roots it should be fairly safe from recognition.

Anti-tank mines are a two-edged weapon, and every precaution must be taken so that our tanks do not negotiate them. In the war of 1914–18 part of an American tank battalion was destroyed by passing over a British mine-field that had been laid some months before.

The most suitable natural obstacle to the tank is the water gap—hence the importance of the river line. A railway line with embankments and cuttings is also useful. Swampy country, as well as very hilly country, is unsuitable for tanks. To these obstacles it is usually possible for the defenders to add artificial ones. These vary enormously according to the time available. The size of the obstacle required depends, of course, on the type of tank that it is required to oppose, as the critical vertical height which a tank cannot climb is the height of the front sprocket-wheel of its track from the ground. Rows of low tree-stumps a foot or two high are useful to catch tanks between their tracks and 'belly' them so that the tracks are raised off the ground and are therefore useless. Wire concertinas are not very effective against a tank, but a more effective wire arrangement known as Dannert wire, now in use, is some hindrance to a light tank, and there are in existence devices whereby the tank trails 'tank anchors' after itself.

An important matter in the defence of an area is the existence of anti-tank localities—self-contained centres of resistance which are tank-proof. These limit the possibilities of the hostile exploitation of an attack. A good example of this is the village, which can usually be made tank-proof with careful planning and a day or two of preparation. Sapper assistance is desirable for this, and a definite garrison must be provided for the defence of the village. It would then be divided up into areas tactically and administratively self-contained and each capable of all-round defence, there being a central keep for the headquarters of the garrison. An infantry battalion as at present organized with its Bren guns, anti-tank rifles, and mortars is well suited for this job, and the compressor tools of a sapper field-company are very useful for making loop-holes, knocking through the walls of houses, cutting down trees, and so on. Bren guns should be mounted in the centre of a room firing through a window in an inconspicuous manner, obstacles in all directions should be co-ordinated with the defensive fire-plan, the mortars of the garrison being used for covering dead ground. There is hardly any limit to the defensive possibilities of a village locality if time avails for the purpose. At the same time there are few obstacles that tanks cannot overcome, given time and freedom from molestation. The real use of obstacles is in conjunction with the weapons of the defence.

In the war of 1914–18 18-pounder or 13-pounder field guns were our only anti-tank weapons and neither was designed for this particular purpose. A direct hit is required, and the shell was unnecessarily large for this and the gun much too clumsy for quick handling. All armies are now provided both with anti-tank rifles and anti-tank guns—weapons with widely different characteristics. It is a matter of some doubt whether the anti-tank gun should be regarded as an artillery or as an infantry weapon, there being a good deal to be said for either alternative. Plate 6 shows the anti-tank gun with which the Royal Artillery is provided. As it is a weapon of opportunity, some anti-tank guns must be mounted in or near the forward defences, and they then require protection against enemy infantry. The best results are undoubtedly secured by withholding fire until enemy tanks are very close, as the element of surprise is so important in their handling. In this connexion it is sometimes forgotten that tanks cannot appear out of the ground like rabbits, and that time and preparation are required in staging a tank attack. The anti-tank gunner has therefore ample warning of the intention of his enemy, and it is usually possible for him to arrange some sort of obstacle in front of his guns; and he is helped by the fact that when tanks are closed down as in an attack, their field of view is very limited. All nations regard the anti-tank gun as being an important feature of the forward defences. As long ago as 1937 it was reported that the Germans had an establishment of 72 anti-tank guns per division as well as 13,000 anti-tank mines per division, and that the number of anti-tank guns was likely to be still further increased. If the number of mines was as stated it would throw a heavy strain on transport facilities.

In their early attacks on the Siegfried line in the autumn of 1939 the French were stated to have advanced with heavy tanks which were intended to deal with the anti-tank gun, and that these tanks were capable of resisting penetration even with direct hits. In general it would seem that the battle between guns and armour is being waged in military armoured formations on very much the same lines as it has been in the world's navies for nearly a hundred years.

Supreme among the anti-tank weapons is the tank itself. Tanks of many nations now carry guns suitable for use against other tanks. Tank duels are a likely possibility in war under mobile conditions between two forces whose tank forces are comparable, but there are many ways in which a force whose tanks are very limited in numbers or inferior in quality can avoid such action. It must be remembered that a direct hit on a small fast-moving object like a tank under battle-field conditions is not going to be easy—it will be comparable to the job of hitting a running hare with a rifle bullet; and although the cumulative effect of anti-tank defence in all its various phases is considerable, the tank still remains by far the most potent offensive weapon on land yet invented.

The German doctrine seems to envisage the use of armoured divisions with a good deal of boldness and daring and the rapid exploitation of any success. It may easily happen that a Pyrrhic victory is thereby secured, as tanks once destroyed are not easily replaced, and trained personnel is also limited. Mobile engineers can also do much to frustrate such action by the drastic destruction that they can bring about in a short space of time.

Genghiz Khan with his Mongol horsemen used to seek out 'soft spots' very much on the lines of the German regulations, but however powerful modern armoured formations may be, they cannot hold the ground that is won, and unless the infantry follow close in their wake any initial advantage will be quickly lost.

But mechanization is not merely a matter of armoured fighting units nor of armoured divisions, of which many armies now possess a number organized in widely different ways. It affects the whole field of strategy, tactics, and administration. The fate of armies now depends more than ever on the time factor. In its fluid phases modern war makes higher demands upon the commander than ever before—it is essential that he should cultivate quickness of perception and soundness of judgement. Careful timing of the mobile armoured formations is more than ever vital to success. The exploitation of success and the quick movement of mechanized forces through a gap that has been made becomes a paramount consideration, though it must be remembered that the demolitions that are possible with modern power tools can effectively hold up mechanized formations. Indeed, the engineer becomes even more important in holding up attacks than the gunner or the airman. Mechanization has made the human factor more and not less important than formerly. There are certain factors whose importance remains unaltered and unalterable—firmness, quick and confident leadership, sympathetic treatment. But over and above these, quickness in the uptake, technical knowledge and vision are far more important than ever before. The mental equipment of the leader of to-day must be a good deal more comprehensive than even a generation ago.

One subject in which mechanization has brought about vital and widespread changes is in the matter of supply. Movement has, of course, always been of vital importance to armies. On the marching power of the legion rested the Pax Romana. Rightly was the Roman soldier called *impeditus*, because in his pack he carried no less than seventeen days' rations, which together with his shield, sword, and helmet made a heavy load. It was this load that gave him the power of distant movement and strategical independence. So it was this that was the means of imparting true mobility. Our system under the conditions of a major war is that a pack-train containing the division's daily requirements of rations and supplies runs daily from base to railhead; from here a supply column of the R.A.S.C. carries stores to the refilling point, whence the formation's supply company bears supplies to a delivery point near the troops. On the soldier himself is merely one day's emergency ration, and in his regimental transport is the unconsumed portion of the current day's ration. In rear is the supply company and the supply column, each carrying a day's rations, so that between the soldier and railhead are four days' rations. Ammunition follows the same stages. It will be seen how firmly wedded to the supply-route the Army has become. Moreover, the ration is no longer the simple items of meat and flour which satisfied the Roman legionary.

How is it possible for the soldier to gain mobility? Surely the answer is found in terms of the machine, if rightly used. The cross-country vehicles, for a start, enable us to be no longer tied down to linear one-dimensional movement based on railway and road. At present we have mere motorization which gives some assistance, as is made plain by the large reduction of the personnel of the war-time infantry battalion, but it does not achieve the total abolition of the horde-army and its colossal needs. There can be no doubt that as a start the Army should adopt far more labour-saving devices. Industry to-day presents us with a whole host of these, but the soldier lags behind the civilian in the economy of time and effort. Whoever thinks of the removal by electric power at high speed, and with no physical labour, of dirt from the many articles which the soldier must use daily in his peace-time routine? It may be argued that this has little relationship to war, but 'custom hangs upon us like a weight', and it is the habit that counts. There is much room for the use of more machinery in the organization that is inevitable for a field army. Moreover, if mobility is to be obtained, the fixed railhead must be replaced by the mobile base. Even as at present we have a variety of mobile administrative units, corps field parks, army field workshops, light repair sections, and the like, and this principle must be extended as in the R.A.F., whose ground organization is completely mobile. Such a mobile base would serve both for supply and repairs, carrying enough stores for a week's maintenance and perhaps some emergency reserve. If the threat from the air is considerable the base will have to be dispersed into several, but the same principle would apply.

Petrol-supply is still the 'Achilles heel' of mechanized formations, though something is being done by replacing the petrol-engine by the Diesel, so that relatively non-inflammable crude oil is used. To-day our fighting vehicle carries sufficient petrol for two normal days' marches, and enough is carried in the formation's transport for another day. Every unit is expected to have enough to allow a certain mileage for its vehicles every day. Petrol itself is regarded as simply one commodity in the unit's daily supply requirements. It would seem that here again the lesson from civilian practice might be learnt and larger fuel-tanks supplied. The petrol-can, which is heavy in relation to its contents, still looms too large in army practice, and the 3-ton lorry, with its bulk content of 700 gallons, must take its place.

In the French Army a somewhat daring innovation has been introduced in fitting arrangements in some of the forward army vehicles enabling wood to be employed in an emergency, and in a proportion of the motorized infantry, wood-gas is generated in a stove. According to the press, heavy transport lorries are equipped with dual-supply systems of wood-gas and petrol. The same principle has been applied to the lighter transport and even to touring cars. *Wood is obtainable everywhere in France and the* cars can *run 100 kilometres on 37 kilograms of wood.* Charcoal and coal can also be used. It requires nearly ten minutes to obtain gas from wood, and this is a drawback. It is necessary for the gas to pass through several purifiers before being fed to the induction pipes. But it is worth a good deal for the mobile column to be saved from the haunting dread that its fuel-supply may be cut off and operations rendered impossible.

CHAPTER IV

ARTILLERY TO-DAY

THE word 'artillery' is derived from the old French verb *artiller*, meaning to equip with engines of war. In the Old Testament mention is made of 'engines invented by cunning men to shoot arrows and great stones'. The medieval *catapultæ* and *ballistæ* were very powerful, and even when a propelling agent as strong as gunpowder was applied, the supersession of the older weapon only took place gradually. The early guns were mainly used to batter the walls of fortifications—Crécy was the first example of the use of field artillery. The outstanding example of artillery work in the fifteenth century was the siege of Constantinople in 1453, when the Turks used a large force of artillery. Some of these pieces actually survived to engage a British squadron in 1807, when a stone shot weighing some 700 lb. cut the mainmast of Admiral Duckworth's flagship in two.

In the time of Henry VIII the principal heavy ordnance in use in the field was the culverin, the lighter pieces being called sakers and falcons, the latter being 2-pounders.

In the sixteenth century the guns were still mainly served by civilians with no technical skill and often possessing other disabilities. In the reign of Elizabeth some of the Tower gunners were over ninety years of age. In that reign, however, the old wrought-iron guns of Plantagenet times had almost passed away, and in their stead bronze and cast-iron pieces were used. The size of Elizabeth's artillery may be gauged by the fact that 3 horses could draw the 'falcon', 14 horses the culverin, and 24 horses the largest gun which was alone called a 'cannon'. By degrees it was recognized that specialists must be used in order to get the best results, and the Royal Regiment of Artillery came into existence in England in 1716. Artillery drivers only became soldiers some eighty years later. About the middle of the eighteenth century, when England was certainly abreast of other countries in the organization of her field artillery, the guns in use varied from 24-pounders to 3-pounders.

During the Napoleonic wars the French artillery steadily improved both in performance and in manœuvring power. Much of Napoleon's success depended on his 'artillery preparation', which was much in advance of anything hitherto attempted. His 'case shot' attack, involving a swift move by the guns at a gallop far in front of the infantry, soon became world-famous.

No very great change was witnessed in the nineteenth century until the introduction of the rifled musket put an end to the artillery tactics of the smooth-bore days. In the American Civil War infantry, armed with a far-ranging rifle, kept the guns beyond case-shot range. If the battalions went into close range their losses were out of proportion to their effectiveness. It was the Prussian improved artillery and their better tactical training that was to contribute much towards the defeat of the French in 1870–1. At Sedan the French Army was enveloped and annihilated by the fire of nearly 600 guns.

The quick-firing gun came into existence in our army a little before the end of the nineteenth century. The mechanical absorption of the recoil permitted of a higher rate of fire, since the gun did not require to be run up to be relaid after every shot. Until the arrival of smokeless powder this was of little value, as time had to be wasted in any case till the smoke had cleared away, but smokeless powder and recoil springs enabled a high rate of fire to be achieved. At the same time a shield was applied to the gun for the protection of the detachment, but until a non-recoiling carriage was devised, the gunners had in any case to stand clear of the recoiling gun, so that a shield was of little value.

Nevertheless, the power of modern artillery owed even more to the improvement of the projectile than to that of the gun. The shrapnel shell was a British invention, but, characteristically enough, the French was the first nation to realize the significance of the time-fuse and the multiple charge. These two together achieve a rain of bullets suitably spread out and over the heads of infantry in the open. Shortly before the South African War, 1899–1902, there was a reappearance of the field howitzer with its special application to troops sheltered behind works. The howitzer was also developed as a heavy siege weapon.

In the war of 1914–18 there was comparatively little change in the actual field artillery itself, but with the arrival of trench warfare shrapnel had but a limited use, and by degrees the high-explosive shell with percussion fuse became more and more important. It is difficult to imagine now that at the beginning of that war no high-explosive shell at all was carried by field batteries.

Our own artillery in 1914 consisted of the 18-pounder field gun organized in 6-gun batteries, an admirable weapon, if not quite so perfect a gun as the French well-known 'seventy-five'. We also had a lighter and more mobile gun, the 13-pounder, for use with the cavalry. Batteries of 5-in. howitzers were also provided. Guns have a high muzzle velocity which gives them a long range but involves a comparatively flat trajectory; howitzers have a comparatively low muzzle velocity and a high trajectory. The howitzer has a shorter range but greater shell power, and is able to search ground behind cover which guns, owing to their flat trajectory, cannot reach. With each division there were 3 field artillery brigades each of three 18-pounder batteries, together with a howitzer brigade of 2 batteries of 5-in. howitzers. What was then a brigade is now called a regiment. For heavy artillery we took into the field 4-gun batteries of 60-pounders on the scale of one per division.

The enemy was soon to teach us how inadequate was this scale of what would now be called medium artillery, and by degrees far heavier weapons, with guns and howitzers, were added. The Navy helped in this, and heavy naval guns on railway mountings contributed towards lessening the disparity between the British and the German heavy ordnance. As the war went on the amount of heavy artillery and the amount of ammunition used per gun steadily grew. The high-explosive shell was also found to be more suited for trench work than shrapnel, and the use of the former steadily increased. By degrees the tactical method of handling the guns was considerably modified, mainly due to artillery survey, and as this feature has persisted, some mention of it is required.

Sound-ranging involves the location of enemy artillery by timing the arrival of the sound at a number of surveyed points in our own lines. It also deals with the ranging of our own guns on active hostile batteries and the location of the area shelled. Further, it enables the nature and calibre of hostile guns to be estimated. It was first conceived by a French artillery officer named Captain Bongier in the autumn of 1914; the first British sound-ranging sections were in action at Mont Kemmel in Flanders in July 1915, and within a year over twenty British sound-ranging sections were in use on the Western Front. Though the technique of sound-ranging is a little complicated the principles are fairly simple. Five microphones are placed in the open a mile or so behind the forward defended localities and around about a mile apart. Each of these microphones is connected by cable to the head-quarters of the organization. The microphone consists of a tiny platinum wire heated by an electric current. When a sound comes along it cools the wire slightly, thereby altering its electrical resistance, and the change in the current is instantaneously recorded by a slight 'break' in a galvanometer, also at head-quarters. This 'break' is recorded on a moving film working somewhat on the lines of the barograph, but moving very much more quickly. It is thus possible to measure with considerable accuracy (within one hundredth of a second) the instant at which the sound reached the microphone. Fig. 3 gives diagrammatically the layout of cables and Fig. 4 shows a record obtained from all five microphones. In order to avoid the necessity for the moving film to be continually working, an officer is stationed at the advanced post (AP in Fig. 3) so that the sound reaches his ears before arriving at the microphone. He then presses a key for a second or two, and during this time the sound reaches all five microphones. The great majority of 'unwanted' sounds are thereby eliminated. Sound-ranging depends on an estimate of the speed of sound, and this is affected by wind and temperature and is therefore only approximately known; nor can sound-ranging be carried out when the wind is unfavourable. But it is so useful and especially in circumstances when foggy conditions allow of no observation that it has revolutionized counter-battery methods, and added enormously to the capacity of heavy guns for knocking out enemy artillery.

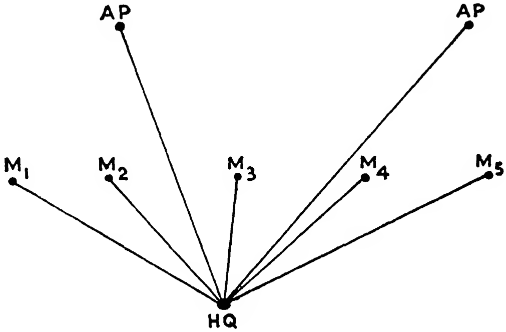

FIG. 3

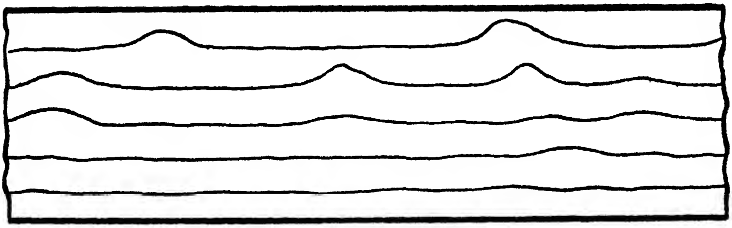

FIG. 4

Together with sound-ranging was developed flash-spotting, which allows of the location of enemy guns by visual observation from the ground. Flash-spotting involves no correction for wind and weather and is therefore more accurate than sound-ranging. Indeed, guns have been located by this means at a distance of 12 miles with an error of less than 100 yards. It requires a less elaborate installation than sound-ranging, and as no photographic development is required, it is somewhat quicker. It does not, however, provide the subsidiary information that sound-ranging obtains, and in misty weather it is, of course, quite useless. It is feasible by day as well as by night but it is difficult in bright weather. These two methods of locating enemy guns are to a large extent complementary. But artillery survey is much more than the mere location of enemy guns, and it has revolutionized the whole technique of artillery work.

'Survey' is defined, with the Olympian detachment that distinguishes official publications, as the determination of the relative position of points on the earth's surface. It becomes artillery survey when one point is the gun, another point is the observation post, and a third is the target. Actually survey as applied to artillery is a very wide term, including every process of fixing targets. One of the best survey instruments in the Royal Regiment is the gun itself. Napoleon's 'case-shot' attack was aimed at concentrating the fire of artillery at the decisive point, and if possible to produce it as a surprise, and that is exactly the aim of artillery survey in artillery tactics to-day. In 1914 each battery entered the fight more or less on its own. A line was laid to the observation post, and what is called 'registration' was carried out, which involved firing a few rounds to get the right corrections. The result was that, from an artillery point of view, a battle degenerated into a vulgar brawl over which no officer above the rank of battery commander could exercise more than a limited control.

Survey now makes it possible for one battery to determine the line, range, &c., of the target from another one in action without previous registration. Surprise is achieved because it is possible to concentrate the fire of a mass of guns at the right time and place, and to produce that fire with the registration of a minimum number of guns, or in some cases with no registration whatsoever. The fact that the guns can keep silent until the moment that they are wanted enables casualties to be avoided, as enemy sound-rangers and flash-spotters cannot locate their position until the vital moment.

The actual technique of artillery survey cannot be elaborated in a short résumé, and difficulties due to such considerations as the time-factor arise, but the whole of artillery tactics has been very much modified. Survey personnel now exist in each battery, and there is with every corps an artillery survey regiment, consisting of a sound-ranging battery, a flash-spotting battery, and a survey battery. The sound-ranging technique has been very much mechanized since the war of 1914–18, and location of an enemy gun may be quickly obtained, though not in very fluid warfare. Survey under favourable circumstances contributes a good deal to the target-finding capacity of the gunners. Direct visual observation, even with aircraft to help, is by no means always practicable, and if the enemy cannot be located it may be necessary to seek him out by reconnaissance. It is far pleasanter to shoot him down in comparative comfort from behind a hill than to rush upon him in a noisy and malodorous armoured fighting vehicle. Surveying a target is both more pleasant and more healthy than being one.

Artillery in the field is now classified as mountain (used in India only), horse, field, anti-aircraft, medium, heavy, and super-heavy. All these, except heavy and super-heavy, have the mobility to march and manœuvre with a division. Mountain artillery is carried on pack, while hardly any horse-drawn artillery remains now that the field force is entirely mechanized.

There have been some outstanding changes in artillery practice in recent years, and artillery tactics have been very much simplified by the introduction of the gun-howitzer. The old 4·5-in. howitzer used to have variable charges enabling the muzzle velocity, and of course the range, to be varied. It was never found possible to do this with the 18-pounder, and hence, right through the war of 1914–18 and for many years after, the complication of guns and howitzers together was necessary. It has now been found possible to overcome this complication, and the new British gun-howitzer fires a heavy shell over a wide range enabling it to be used for a variety of purposes. It is, moreover, capable of being used in the field without serious wear far longer than was the case with the old 18-pounder, and the consequent inaccuracy of shooting is therefore a less serious factor than heretofore. The simplification of ammunition supply alone is a conspicuous advantage.

It is of interest to note that in the German Army the old

77-millimetre gun—which found its way as a trophy into many an English village—seems to have disappeared, and it has been replaced by a 10-centimetre howitzer, which with its five charges is expected to do the work of both howitzer and gun, though its range is inevitably somewhat short. The French have adopted a somewhat similar expedient, and so, after some forty years of fruitless trial, Britain, France, and Germany all seem to have arrived at a solution of this problem.

The British divisional artillery is now organized on very modern lines, and is capable of operating so as to bring into effect the dominating principle of concentration which has been so vital ever since Napoleon's time. Artillery fulfils its role by interference, which causes casualties and shatters the enemy's morale; by neutralization, which stops the fire of enemy weapons; and by destruction, whereby enemy defences and material are destroyed. Artillery is normally dependent for fire effect on observation of the target, i.e. the guns are normally placed in indirect positions quite out of sight of the target. The selection of the observation posts is a matter of great importance, and if ground observation is not possible or is ineffective, observation from the air must take its place.

The only other gun in the division itself is the anti-tank gun, of which some mention has been made in the chapter on mechanization, but there is a wide range of weapons behind divisional head-quarters. Foremost among these is the medium artillery including both guns and howitzers. These weapons are mainly in use for counter-battery work, i.e. knocking out the enemy field guns and also for destroying his ammunition and engineer and supply dumps, for harassing fire beyond the range of field guns, and for important targets in the open. The next category is classed as heavy, and Plate 7 gives an illustration of this type. This gun, and howitzers in the same category such as that also illustrated in Plate 7, can be used for distant targets such as roads, head-quarters, dumps, and even kite balloons. They can be used for the destruction of strong defences.

The last type of gun is the super-heavy class. Transport difficulties come in here and special bridging facilities are required in many cases. The 9·2-in. gun is in this category. It is a weapon throwing a high-explosive shell. It is best suited for railway mountings and is an accurate gun, but this type of weapon wears out quickly.

The super-heavy class includes 12-in. howitzers and upwards; such weapons fire very heavy shells and are suitable for the destruction of bridges, gun emplacements, and specially strong defences.

Even larger pieces of ordnance can be used in the field and especially on railway mountings. The Germans have specialized in this type of weapon ever since their surprise long-range shelling of Paris in March 1918. It is doubtful whether the long-range gun has many advantages over the aeroplane bomb, which may be regarded in many respects as the equivalent of super-heavy artillery. The heavy howitzer can be suitably employed with a high-explosive shell with delay-action fuse when penetrative power is especially wanted.

ANTI-AIRCRAFT GUNNERY

Nothing has been said so far of anti-aircraft gunnery, which differs in many fundamental respects from land gunnery. The job of the anti-aircraft gunner has some resemblance to that of the sportsman shooting driven partridges, but the greatest shot-gun expert would be appalled by the problem of bringing down a bird flying at 300 m.p.h. at a height of anything up to 30,000 ft.

Anti-aircraft gunnery was first attempted in 1914, when a naval 2-pounder gun was mounted on the roof of the Foreign Office. Various types of artillery were used in the defence of London and are described in General Ashmore's book, but by the end of the war the 3-in. gun was the best and latest weapon. At that time the speed of aeroplanes was relatively small and their ceiling was low, and when Britain began to wake up to the fact that 1914–18 was not to be the war to end war after all, it was realized that the 3-in. gun was incapable of coping with the new type of aircraft. Improvements were made in it enabling it to fire a 16-lb. shell to an effective height of 21,000 ft. (Plate 10). Guns up to 3 inches are mostly fully automatic with a rate of fire of 25 to 30 rounds per minute. This was all right as far as it went, but there was no doubt that a gun firing a heavier shell to a greater height was required, and Messrs. Vickers accordingly produced the 3·7-in. gun. This gun, which is mobile (Plates 8 and 9), fires a heavy shell to a considerably greater height.

A yet heavier gun was required for static purpose in fixed defence, and this need was met by the 4·5-in. gun, with yet greater range and weight of projectile. In America yet more formidable anti-aircraft guns are in use, their 5-in. anti-aircraft gun firing up to 39,000 ft.

In addition to high, straight flying by bombing or reconnaissance planes flying at high speeds up to 300 m.p.h. at 25,000 ft., there is also the possibility of low-flying attacks, dive-bombing, and hedge-hopping by fighting planes against ground objectives. The Navy meet this form of attack by their multiple pom-poms, and the Army uses similar methods. The speed of such aircraft may be very high owing to the extra velocity due to the dive. The only possibilty of meeting this form of attack is on shot-gun lines—or a more apt description is that of 'hose-pipe' firing. The gun for the purpose is one with a high rate of fire, its small shells or bullets being propelled in a stream of missiles much as a fireman directs a stream of water from his hose-pipe. The infantry have their Bren gun on the special anti-aircraft mounting for this type of attack (Plate 3), and a high proportion of tracer ammunition is desirable.

The gunner, however, wants something more formidable, and hence the Bofors 2-pounder, a Swedish weapon which is now made in this country under licence (Plates 9 and 10). The Bofors 2-pounder gun is mobile and is supplied to the light anti-aircraft batteries. It must be remembered that while the shell is in flight the target will travel well over a mile if flying at a moderate height, and furthermore ranging is impossible since bursts on the line of sight can alone be observed—moreover, there are no natural features to assist as there are on the ground. Furthermore, damage can be done to wings and fuselage without upsetting the flying power of a plane. The vulnerable parts of an aeroplane are the pilot, the controls, and the engine, and in size they may be regarded as a solid some 10×4×3 ft. There is obvious difficulty in getting a direct hit on such a small fast-moving object. Considerations of weight forbid effective armouring, and if this target can be hit by a fragment of the shell alone, success is likely to be achieved. Hence a high-explosive shell is used with a time-fuse. With the 3-in. gun the shell disintegrates into smallish fragments, and the burst should be within 45 ft. of the plane. With the 3·7-in. gun the burst at an even greater distance should be certain of immediate success. The calibration of the fuse-length to bring about the burst at the right time is in itself a problem.

Actually, a feature of German air-raids on British naval bases in the North has been that many enemy aircraft, not immediately shot down, received such damage to petrol system, oil supply, &c., that they came down at sea or in neutral countries.

Except when on bombing or photographic duty a plane will rise, drop, or sway from one side to another, and it is pretty sure to be 'jinking' if shells are expected. The existing predicting apparatus is designed on the assumption the aircraft will remain at a constant height, course, and speed during the time of flight of the shell. Actually it does nothing of the sort, and the discrepancy may be quite considerable, so that in order to engage a target it is essential to know:

1. The present position of the target.
2. The future position of the target.

The instruments to determine the present position are the identification telescope and the height-finder (Plate 11). The identification telescope is merely one capable of accurate levelling and orientation and with which the bearing and angle of sight can be measured at any moment.

The height-finder is an instrument that works on the same principle as the ordinary range-finder. Considerable skill and practice are required by the height-finder team to enable the readings to be taken quickly and accurately. The computations of the future position of the target as well as the calculations of the ballistic data to enable the shell to burst in close vicinity of the target are performed in a most ingenious calculating instrument known as the predictor (Plate 9). This instrument is certainly the most intricate and the most ingenious instrument in use in the modern army. It requires a detachment of six working numbers, and, as with height-finding, a great deal of practice is required if accurate results are to be obtained. The data calculated by the predictor are transmitted electrically to the gun, where the layers follow electric pointers and thus train and elevate it. The fuse-setting is done automatically and this calculation is also done by the predictor.

There can be no doubt at all that the predictor has entirely revolutionized anti-aircraft gunnery. In the war of 1914-18 it was a commonplace that the 'Archies', as they were called, plastered the heavens with wild shell-bursts and the percentage of hits was incredibly small. Wags used to say that the Archies were one of the three most useless things in the world—the other two may be left to the imagination.

But even now we have not reached the end of the anti-aircraft gunner's troubles. He cannot shoot up an enemy until he locates him, and this itself is a major problem. The higher the target the more difficult it is to locate. Very often the first warning of its approach is the sound, and something has been written in another chapter on sound-location.

The observer corps exists for the purpose of giving warning of the arrival of enemy aircraft off the coast. Although the principles involved in their work are simple in the extreme, their application requires the most careful organization, as the information has to be communicated with extreme rapidity if it is to have any value. Furthermore, in order that gunnery may be accurate, certain corrections have to be applied which depend on meteorological information. Meteorological conditions vary considerably with the height, so that the higher the target the more approximate will be the meteorological data.

So much then for anti-aircraft gunnery under daylight conditions. During darkness neither defending aircraft nor anti-aircraft gun can carry on with much prospect of success unless the target is illuminated. In this connexion two separate zones have to be considered—one is the aircraft fighting zone, the other is the artillery zone where the guns engage the enemy. For various reasons these zones must be widely separated. In the former zone the actual illumination of the target is not essential, though desirable, and steady 'pointers' are required to enable fighters to make contact. Excessive illumination is undesirable, and adequate lighting is obtained by lights spaced at a suitable interval throughout this area.

In the latter zone good illumination is essential, and each pick-up is required to allow for the operation of instruments. About half a minute is required from the time of first illumination until the gun is fired. A subsidiary function of a detachment is to guard itself against low-flying attacks. With this object each searchlight station is equipped with a Bren gun on anti-aircraft mountings.

The Searchlight Regiment, or Battalion, as it was called in the Territorial Army, comprises head-quarters and three or four batteries (formerly companies). Each battery contains four sections and each section contains six searchlight detachments. The detachment is equipped with power unit, projector and lamp, sound locator, and light machine gun. The latest type of sound detector is a beautiful piece of mechanism whereby the searchlight is automatically put on the target as soon as the 'listeners' are on, an operation which takes only a few seconds with a trained crew.

The beam candle-power of the 90-centimetre projector is about 200 million, and it throws a beam under optimum conditions a distance of several miles. Star shells are available for illumination at yet greater height, as also when it is not desired to divulge to the enemy the position of the searchlight.

It is essential that the searchlight detachment should be trained as a team so that every man is working in conjunction with his neighbour, not unlike the way a rowing crew works together under the orders of a cox. With a well-trained detachment a target should always be illuminated within half a minute of its first becoming audible to the listeners.

In fine, the basic conditions for effective anti-aircraft fire are a good information service and a well-planned distribution of fire from the batteries. Above all, several groups of batteries should not engage on the same target or other bomber groups may get through unattacked.

The U.S.A. anti-aircraft artillery are at present trying infra-red rays in conjunction with listening instruments. It is hoped by this means to fix the position of an aeroplane before the attack with such accuracy that the employment of searchlights can be entirely foregone. The idea is ingenious, but it is doubtful whether practical considerations will enable lighting to be dispensed with, at any rate for a very long time.

The hostile bomber attacking Great Britain has to face first the fighter planes—and his experience in doing so is not altogether to be envied—and after that anti-aircraft guns are his next concern. These, as has been seen, are organized on a far more scientific basis than was the case in the war of 1914–18. But even with these two obstacles in the way, there can be little doubt that some bombers will get through, and the important matter is to ensure that the losses they sustain are in excess of the damage they can inflict. In some towns such as London there are also balloon barrages to negotiate, and the last line of passive defence is the A.R.P. organization, or P.A.D. (passive air defence), as its military brother is denoted.

In America experiments are being carried out with a 'parachute shell' capable of trapping aircraft in a net made of steel wire up to a height of 25,000 feet. The shell has a very long case, and when it reaches the required altitude the nose of the shell falls from the case, pulling out hundreds of feet of steel tape which is attached to a parachute. A barrage of such shells would make a network that no plane could pass through, and the device would make such defences as the balloon barrage as antiquated as a 'penny farthing' bicycle. The weakness of the arrangement is the danger to aircraft of the defender's side.

Much has been said and written about A.R.P. The efficiency of the organizations that have been set up varies in different localities, but what is in general most necessary is a right sense of proportion. There are two principles which are to some extent mutually opposed. One is 'carry on' and the other is 'safety first'. When they clash, the first is by far the most vital in time of war, but the second tends to be in evidence in some cases. In civil defence the military maxim of considering the matter from the enemy's standpoint may be ignored. His object in conducting air raids is to hamper us in the prosecution of the war, and we are playing his game if there is to be widespread dislocation of normal activity whenever an enemy raider crosses the coast. It is essential that production shall carry on at home without intermission, even though casualties sustained are somewhat increased. Evacuation of children and the aged is, of course, admirable, but the same can hardly be said of workers making a dive for the nearest cover at the slightest threat. Even the black-outs, essential though they be, were first carried out on the highways to an extent that made the toll of accidents all too heavy. It is illogical to permit a safety device so comprehensive in its operation, that the last thing it ensures is safety. Moreover, money spent on passive defence must needs affect what is available for the active prosecution of the war—to use sand-bags in excess of what is necessary in towns that have no military or strategic value may mean a shortage in field defence at the front. No one wants to minimize the admirable efforts —mostly voluntary—of A.R.P. workers, but it is often the case that the most active localities are those that are least vulnerable. Even at the start of Hitler's War, and before a single bomb had found its way to British soil, it was crystal clear that the system of a universal 'taking to ground' when the syrens' melancholy wail was heard would both affect adversely the nerves of many, as well as interfere with production. It is, incidentally, difficult to understand how incendiary bombs on the roof of a house are to be coped with if everyone is in the cellar!

Experience after the outbreak of hostilities soon showed that the Royal Air Force must decide whether warning should be given, and after that syrens were no longer sounded as a matter of course whenever enemy aircraft flew over British soil.

The alternative policy is for all able-bodied men and women to carry on, at any rate until anti-aircraft guns signal the near arrival of enemy aircraft. Everyone knows that the best way to avoid worry is to keep busy, and the population in general and munition workers in particular should be encouraged to go on with their work, and it should be a point of honour to do so as long as possible. The chances of being killed in an air raid in time of war are only comparable to the chances of being killed on the road in time of peace, and the first duty of the citizen is to do all in his power to help to win the war. Nor will this be achieved by ringing every attractive target in the country with guns and search-lights, nor by the employment of too great a part of our resources on passive defence. It is not easy to strike a happy mean between the conflicting claims of anti-aircraft defence, balloon aprons, and the like on the one hand, and purely offensive weapons on the other.

CHAPTER V

MILITARY SIGNALLING

THE signals branch of an army is the means whereby the command issues its orders to the fighting troops and its administrative services, and it is essential that the relations existing between staff and signals should be as close as possible. Just as in the comparative anatomy of animals the nervous system became more and more complicated as evolution proceeded, so it was in the army. The service whereby the staff communicates its will to the various branches has become more and more complicated as warfare has become more complex. The armies of the world, right up to the Middle Ages, depended mainly upon simple orders—very often of a verbal nature[1]—and communicated by mounted orderlies or esquires. Primitive visual and aural appliances were also used, and it is well known with what amazing rapidity messages are passed by smoke signals and by drumming in tropical Africa.

The first definite mention of visual signals, other than mere beacons such as were used to herald the arrival of the Spanish Armada, is found during the Napoleonic wars, when semaphores were constructed on hills and formed a chain of stations across France. Such hills were known as Telegraph Hills, and the name has survived in various localities in England. Victor Hugo gives a graphic description of the working of one of these stations in one of his books. The Admiralty had a chain of such stations for message work between London and Portsmouth and London and Liverpool.

Colonel Morse, after whom the Morse code was named, was the pioneer in the use of electric telegraphic signals,

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[1] Verbal messages by 'a chain of orderlies' are very much discouraged in the modern army. It was stated in the war of 1914–18 that when an officer commanding the forward elements of a battalion in attack sent by this means the simple message 'Going to advance. Send me reinforcements' his harassed colonel at battalion head-quarters was amazed to receive the following: 'Going to a dance. Lend me three and fourpence.'

his experimental work being carried on between Shooters Hill and the Rotunda at Woolwich. He used a volta pile in place of a battery; electric cable in actual war was first tried out in the Crimea. The Austrians in their war against Prussia in 1866 first attempted burying cable, a plough being used for this purpose. It is said that inductive wireless telegraphy was tentatively tried out in the American Civil War.

In the British Army, telegraph units existed in the Royal Engineers nearly seventy years ago, Earl Kitchener being a subaltern in C Telegraph Troop in 1873, this being one of the earliest units. We first used telegraph in war in the Bechuanaland campaign, both air line and field cable being employed. The cable was copper-wound, but this proved unsatisfactory and was replaced by steel-wire cable insulated by rubber, much on the lines of that used by the Austrians in 1866.

It was Colonel Cardew, R.E., who invented the buzzer (called the vibrator in those days) whereby relatively small and easily transmitted currents could be used for signals on faulty forward cables, and this method is still one of the most important means of communication for use in the field.

In the Boer War there were two signal systems in use: one was for the keeping up of communication between the many mobile columns, and this was effected by regimental signallers using visual means. In a country of constant sunshine studded with numberless little hills, the heliograph was the ideal instrument for this. There was also the telegraph whereby communication along the railway lines and lines of blockhouses was maintained. This was laid and operated by sapper formations, a complete telegraph division being sent to the seat of war at an early stage. Under the special circumstances of this war little loss of efficiency was involved in two complete signal systems with little liaison or co-operation, but it was appreciated that waste and overlapping would be inevitable under European conditions, and in 1906 a committee (of which Lord Horne, afterwards Commander of the First Army in France, was a member) recommended that all message routes required by the Army in the field, whether by telegraph, telephone, visual, or message-carrying agency, should be organized under one central controlling authority. As a result of this the Signal Service R.E. came into being in 1912, although it was not so comprehensively organized as the 1906 committee had wished, the gunners in particular keeping their own signal system independent of the new service. The old Telegraph Companies R.E. disappeared, and in their place appeared larger and more comprehensive units of which the Divisional Signal Companies were the most important.

The British Army, therefore, took the field in 1914 with a newly organized and comprehensive signal service, which was undoubtedly some way ahead of that of the other belligerents. There were, however, weaknesses due to the looseness of the organization, the relative lack of reserves, and the neglect of the telephone. Moreover, signal personnel had received no training in the use of existing civilian communications in France and Belgium, and in the early stages of the war it was quite common to see cable-laying sections stringing out precious cable alongside existing and unused civilian air-line. In the retreat from Mons it was not long before all the cable in the field was lost to the enemy, and communication after that was mostly maintained by motor-cyclists. Dispatch riders for this had joined up on the outbreak of war and were almost entirely recruited from University O.T.C. undergraduates; each man brought his own machine and there was a very miscellaneous assortment. The Army owes a great debt to the gallantry and resource of these youngsters in those difficult days. Though with very little military training and working under every conceivable drawback, they kept communications going until stores of cable were replenished and less fluid conditions enabled other means of communication to ease the strain. The history of the signal service in France and Flanders has been ably written by R. E. Priestly.[1] It shows how the

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[1] *The Signal Service in the European War 1914–1918*, Major Priestly, M.C. (Institution of R.E. and the Signals Association).

signal service was built up from an establishment of 78 officers and 2,387 other ranks for the Signals branch in August 1914, until in November 1918 there were 2,116 officers and 56,792 other ranks serving with the signal service in the various expeditionary forces.

During this period many changes were made, mostly involving increased personnel and equipment to provide for the increased responsibilities. It was soon realized that the original proposal of the 1906 Committee to include gunner communications within the responsibility of the signal service was correct, and in 1915 additions were made to divisional signal companies to provide for this. Later on, the divisional companies incorporated the signal sections, who were responsible for the internal communication of artillery brigades as well. Machine-gun signal sections were also added.

The change to trench warfare involved far-reaching alterations in signal arrangements. The heavy shelling resulted in the main communications being driven underground, but the changes were very gradual, as the higher command was reluctant to assume that static conditions would remain for very long. By degrees overland lines in forward areas were entirely given up and the cable trenches were dug deeper; for reasons of security earth return lines were gradually replaced by metal return cables which were twisted round each other as a further precaution against enemy overhearing. Fig. 5 gives the signal communications in an infantry brigade in the line near Ypres in the summer of 1915, and illustrates the kind of communications in vogue at this intermediate stage. Finally, the existence of a state of affairs not far removed from fortress conditions was recognized and cables, very often armoured, were buried in trenches 6 ft. deep or even more, as many as 200 lines being sometimes put in one trench, with manned test-stations along the route and protected signal offices at junctions. The principle adopted was to make all lines safe from the 5·9-in. howitzers which played a prominent part in the enemy's artillery preparation and retaliatory fire. It was also laid down that all signal offices should be

so protected as to be unaffected by the direct hit of an 11-in. shell. This was a policy of perfection rarely attained, but it can be appreciated that the work involved in such a system extending back to some five miles from the trench forward defences was sufficiently onerous. That the work was worth while can hardly be doubted. It was not always appreciated that by far the most important communications in battle were the lines connecting the artillery observation posts with the guns. The volume of fire that a quick-firing gun can produce is such that no attack can survive under the conditions under which they were made in 1916, 1917, and 1918, if the defence gunners are fully informed. It is doubtful whether a staged attack in France under trench warfare conditions ever succeeded when these vital communications were not severed. The area taken over by the Fifth Army from the French at the end of 1917 was deficient in these communications, and lines above ground or in shallow buries were alone available. When the Germans attacked at dawn on 21st March, 1918, all lines from observation posts to guns were cut in the fierce bombardment, and guns were reduced to firing 'over the sights' as the attackers appeared through the fog. The German break-through was completely successful. A week later, on 28th March, the enemy considered it necessary to widen the gap, and several German divisions attacked Arras, which was mainly held by the 56th (London) Division. The buried cable system here had been built up in some two years' hard work and no vital communications were severed. The thinly held outpost line was indeed lost, but the main line of resistance was never seriously threatened, thanks to the devastating gun and machine-gun fire, and all the Germans had to show for the day's work was the piled-up heaps of the bodies of their soldiers who had fallen in the attack.

Although the most important method of communication throughout the war of 1914-18 was undoubtedly air-lines and cable for telegraphic and telephonic use, subsidiary means of communication were continually growing in importance. Visual signalling by flag fell quickly into disuse on the Western Front owing to the number of casualties among the signallers, but it was revived to an important extent in lamp signalling, the Lucas daylight signalling lamp being a useful and handy contrivance. Wireless was in its infancy in 1914, and was only used by the cavalry, and was distrusted, with some reason, by many of the staff. The sets were drawn by six-horse teams, and only three sets were available at the outbreak of war for the four cavalry brigades, and as one of these was lost during the retreat, the new means of communication was hardly initiated under the happiest of auspices. Later on in the war wireless was revived, better sets and better organization being introduced, and ultimately each divisional signal company had its own wireless officer and its own wireless section. The old-fashioned spark system survived until the end of the war, the then new-fangled but now universal continuous-wave system (called C.W.) being regarded with some suspicion. It was somewhat remarkable that these very complicated sets, requiring such careful handling, should be handed over to the artillery signals, who were naturally less expert than the wireless specialists. The advantage of continuous wave over spark is its extreme selectivity and its greater range for a given power, which enabled inconspicuous aerials to be used. Unfortunately the newly designed sets required the most careful adjustments, and there were literally dozens of ways in which they could go wrong. However, continuous wave had come to stay, and soon after the war was over, spark wireless was relegated to the limbo of forgotten things. Broadcasting was also a post-war development.

Message-carrying methods were much developed during the war, especially the carrier pigeon. It was even said by the troops that experiments were being made of cross-breeding pigeons with parrots, with a view to taking verbal messages! The carrier pigeon became a very important means of getting messages back from forward positions, but it is of course only useful in one direction. The pigeon service in the long-drawn-out trench warfare outstripped the forward wireless service in its practical utility, the number of birds used during the offensive on the Somme in 1917 alone being 12,000. It was even found that the pigeons developed an instinct enabling them to avoid gas clouds. The Germans made much successful use of messenger dogs, which were often to be seen racing back from their front lines to head-quarters in rear. We attempted to use this method of message-carrying, and a War Dog School was formed at Shoeburyness under a canine expert. In spite of the most stringent orders, the troops could not be prevented from petting the dogs, and much of their utility was thereby lost. Throughout the trench-warfare battles, the regimental runner was the most reliable message-carrying agency. Their use involved heavy casualties and the method was often slow, but it enabled vital information to be passed on when other means had failed. A novel means of communication much used in the later phases of the war was the message-carrying rocket. This had a range up to 2,300 yds., and heralded the arrival of the missive with a loud whistling. Yet another method of communication, often of considerable use, was by means of aircraft detailed for this purpose and denoted 'contact patrols'.

With the end of the 'war to end war', as the deluded Allies considered it at the time, it was rightly considered that signals had become too important a matter to be merely a branch of the Royal Engineers. Moreover, the signal officer requires a good deal of technical and electrical knowledge, but none of the training in civil and mechanical engineering that is so important to the sapper. Some ten years after the war yet another daughter of the parent Corps of Royal Engineers, therefore, came into being and the Royal Corps of Signals made its début. By this time wireless had become even more important, and in general it may be said that wireless-telegraphy and radio-telephony have replaced the cable as the first and foremost means of army communication, at any rate in mobile warfare. Another feature has been the continued growth of the divisional signal company. Whereas on mobilization in 1914 its strength was 5 officers and 157 other ranks and at the

Armistice 15 officers and 400 other ranks, it has now swollen to a unit of some 500 officers and men—though the man-power of the division itself is now a good deal smaller. A whole host of other signal units exist for the service of higher formations, armoured units, R.A.F. services, railways, lines of communication, and the like.

Divisional signals is, however, the most important, and is the highest unit that is permanent in its composition. It is always the duty of a higher formation to provide the necessary signal facilities for communication to the lower, and divisional signals is responsible for communicating the will of the divisional commander to all units of his command down to battalions and batteries.

To No. 1 company, the largest, is allotted the duty of communicating from head-quarters to infantry brigades and artillery regiments. Also to divisional cavalry, sappers and services, and attached troops such as tank units or R.A.F. formations and advanced landing-grounds. The latter create a special difficulty as they may be so distant.

A section is devoted to wireless and is equipped both with a number of the larger sets which are carried in lorries, and also with the smaller sets which are in trucks and which can be man-handled if necessary. The former set is for long-range telegraphic purposes, whereas the latter is available for telegraph but is more often used for radio-telephony. One of the present-day problems is to devise a satisfactory duplex radio-telephony set that is as robust and as handy as the everyday telephone.

B section is for cable-laying, and until a short time ago the old-fashioned horse cable-wagon survived in the corps as no practical alternative was available. A satisfactory mechanical cable-layer has now been devised and is shown in Plate 12. It carries a small engine driving a drum elevated on the lorry. Fixed to the back of this is a cage in which a man sits and throws the cable out with a crook-stick. With the arrival of this cable-layer, the horse has been given up in the Corps of Signals, as elsewhere in the British Army as far as European warfare is concerned.

C section is for the internal use of divisional cavalry (now mechanized) and is equipped with the larger wireless sets, as the distance over which communication has to be maintained may be considerable.

D section is responsible for operating, and contains the office lorries with the operators for working the various instruments, and signal masters for traffic regulation. It also includes the dispatch riders. Plate 12 shows a typical signal office in the field with a R.A.F. wireless-tender attached. The blue and white flag, visible but not conspicuous, indicates the presence of Signals attached to the head-quarters of a formation.

M section is responsible for technical maintenance, repair of instruments, charging accumulators, and the like.

The employment of No. 1 company depends greatly upon the type of operations that are being conducted. In the approach-march in the vicinity of the enemy, wireless will rarely be used for security reasons. The direction from which the signal comes can be determined, and an army coming into action is like a fleet at sea, in that it often has to dispense with wireless. When contact with the enemy is reached the advance guard is usually split up into vanguard and main-guard. A cable detachment would be moved up behind the main-guard, as a cable detachment from corps head-quarters' signals would probably be laying a cable forward between the main-guard and the vanguard. This is because they would have very little other opportunity, owing to the congested state of the roads, of giving the division any communication with the corps other than by wireless or dispatch rider. Moreover, the division is thus spared the necessity of using its own cable before its brigades deploy.

It is one of the principles of signal-working that what is grandiosely termed a *main signal artery* should be generally maintained. A main artery is a concentration of communication facilities on one route from rear to front, on which are established signal offices and signal centres. In small formations the main artery may be simply a single cable and a route for dispatch riders. Having established the main arteries, the system may be developed and strengthened by lateral communications connecting the head-quarters of one formation with the next one alongside it. In general it is essential to effect economy in laying lines and carrying dispatches. A signal officer must very often refuse to allow telephone facilities, even to an officer of some importance, if the service is not essential, or if it hinders the proper establishment of a main artery. The main artery system is unsuitable in any formation which covers a wide front and where head-quarters are well forward. Nor is it applicable to armoured forces, which depend almost entirely on wireless communication.

No. 2 and No. 3 companies of the divisional signals only exist as such under peace conditions. No. 2 company consists of the sections which are responsible for keeping up communications between the artillery regiments and their constituent batteries, and no. 3 company contains the three sections, called brigade sections, whose job is to keep the brigadier in touch with each of his three battalions. Their communication is now fairly straightforward and is mainly wireless, each battalion head-quarters being provided with one of the smaller sets. It often happens that other units are attached to the brigade, and it is also the job of the infantry to keep in touch with the supporting artillery. Another feature that mechanization has brought in its train is the liaison officer, who speeds quickly from one head-quarters to another with detailed orders, verbal or written. In a mechanized brigade, liaison officers from battalions will be largely employed, acting virtually as super dispatch riders.

At the head-quarters of battalions and batteries the direct responsibility of the Royal Corps of Signals ends, and beyond these head-quarters the signal officer of the formation controls the communications with the personnel and the equipment at his disposal. For example, the battalion signal officer has No. 1 platoon for this purpose with a personnel of over thirty N.C.O.s and men, besides attached orderlies from the companies. The signalling stores—mainly light cable, telephones, and daylight lamps—are carried in a 15-cwt. truck, and 3 motor cycles and a number of push-bikes are available for dispatch riding. Arrangements for communications within the infantry battalion are now somewhat complicated by the arrival of the Bren carriers, which can cover long distances in a short time, but in general the traditional leap-frogging system is as much as possible maintained. In this there is a forward head-quarters in the neighbourhood of the forward companies, and communication is kept by a main artery between this and the battalion head-quarters in rear. In the event of a successful attack the forward head-quarters becomes the battalion head-quarters and another operational head-quarters is formed and connexion established on the line of advance of the battalion. Under highly mobile conditions it is usually necessary to depend mainly on visual communications and cyclists, as there is no time available for stringing out cable, but under less mobile conditions, when, for example, a defensive position has been deliberately prepared, a good deal of cable may be laid, thereby providing safer communications and saving the signallers from danger and fatigue. A real battle is very different from an O.T.C. field day, and it is essential that a considerable proportion of the signallers should be resting and in reserve.

The communications within a battery depend a great deal on the tactical arrangements, but in the event of a battery observation-post being established, by far the most important communication is from this to the guns. The gunner has little use for the Morse code, the spoken word being essential for fleeting targets. If a line can be established, this is by far the most satisfactory arrangement, but in very mobile operations radio-telephony is alone feasible.

A word may be said here about the telephone set Portable D III (Fig. 6), which is widely used throughout the army. This instrument came out early in 1915 and was so successful that hardly any changes in it were found necessary. It consists of a small and inconspicuous metal instrument-case, together with hand telephone set and a separate head receiver. Two very small dry cells are the source of power, and it is equally satisfactory for telegraph (buzzer) or for speaking. These telephones may be connected up by small portable exchanges known as buzzer-switch units, to which all lines are connected. The smaller of these, the 4+3 unit, can accommodate seven 'subscribers', but three are grouped on one indicating receiver. The larger, the 7+3 (Fig. 7), can accommodate ten 'subscribers', also with three grouped on one indicating receiver. Another instrument that calls for some mention is the fullerphone. In the war of 1914–18 it was found possible by the use of amplifiers, which possess the property of largely magnifying a minute current, to pick up the minute induced current that an alternating current, such as a telephone or buzzer, sets up in neighbouring conductors. The Germans were very successful in this, and it was found necessary to adopt some device to obviate the danger. Captain Fuller, R.E. (as he was then), achieved this by a clever arrangement whereby a 'chopper' switch enables the line current to be direct instead of alternating so that it cannot be 'overheard'. The fullerphone that he designed was somewhat delicate, but a new pattern has now been introduced, thereby providing the modern army with a safe and highly portable instrument with most of the old drawbacks rectified. It is to be noted that this instrument is only safe from 'overhearing' dangers if used as a telegraph and not as a telephone.

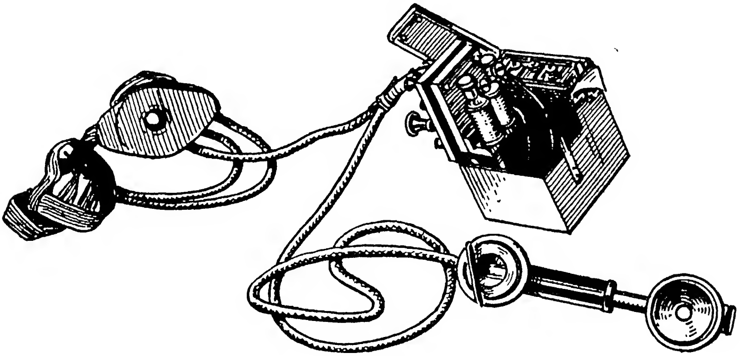


FIG. 6

In post-office work the old Morse code telegraph system has been entirely replaced by one or other of two alternatives. One is the telephone, now commonly used from the small country office to send a telegraph message, this type of message being called in the army the phonogram. But in sending a telegraph message from one big post-office to another the teleprinter is employed. In this a girl types the message at one end and it is received in type at the other. The teleprinter is rather a complicated instrument, easy to work but requiring highly skilled maintenance every 100 working hours. It is due to it that Morse operating is virtually dead in the British postal service, with the added complication that post-office personnel for telegraph operating are no longer available in numbers on mobilization.

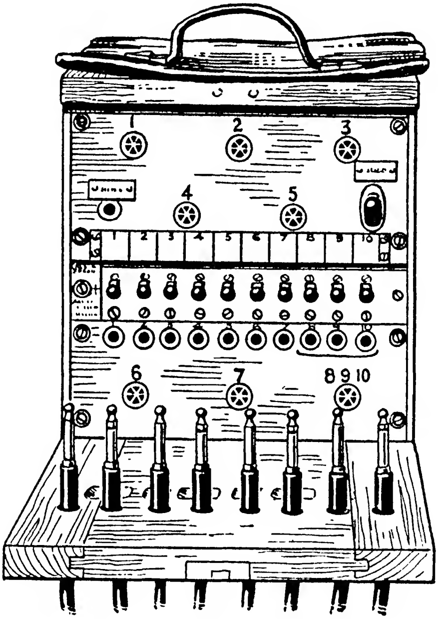


FIG. 7

The formation that presents by far the most difficult problem to the Royal Corps of Signals is the armoured division. Apart from elementary flag signals, wireless is the only feasible proposition here. Moreover, as this involves maintenance and in some cases operation by technical personnel, the responsibility of the Royal Corps of Signals cannot end at unit head-quarters. Tank units therefore have signal sections from the Corps attached to them. Though each tank now carries a wireless set, it can be readily imagined that the facilities in a light tank for carrying the set—let alone its manipulation—are of the slightest. The new light sets for tanks have a special shape suited for the tank interior and enable speech to be carried on between tanks several miles apart, the actual distance depending on the circumstances. The lorry set introduces a problem. Its range makes it a very desirable acquisition, but no tank commander wants an unarmoured vehicle in his command. The signal tank is a possibility, but tanks are expensive things and their proper job is to engage the enemy. But the real difficulty is due to the congested state of the ether. It is, of course, true that the modern sets are far more selective and work on a narrower band than was formerly the case, but new demands for use of the ether are constantly arising. The signal-officer-in-chief controls the allotment of wave frequencies within the army and attached R.A.F. He allots blocks of frequencies to all formations which come directly under G.H.Q. Ten kilocycles' separation is desirable but can rarely be allowed. The other services must have their waves allotted, likewise semi-civilian organizations such as broadcasting and A.R.P., nor must neutrals be forgotten, and no control at all is possible over the enemy use. Moreover, the range of frequencies is limited for work in the field. The shorter waves are very sensitive to varying conditions of terrain—hills, woods, &c.—and for the shortest only visual range is feasible. The Germans have introduced a new and very typical feature in war by broadcasting untrue reports on waves normally used by their enemies, one unexpected result of which was the arrival in Warsaw of a motor-car full of German officers owing to a bogus report on the Warsaw wave that the city had fallen! As regards tank signals, it is necessary to put several tanks on the same frequency. Control by crystal is liable to suffer from the heat inside the tank, and this tends to affect the frequency, but experienced personnel get on fairly well. Communication between adjacent tanks of different formations working on different frequencies is not so easy.

A subject of considerable importance which would require a treatise in itself is signal security, and in every army an organization exists for the interception of enemy messages. Every unit is given a code name, and this must always be used in telephone conversations in front of divisional head-quarters and in all radio-telephone conversations. It avails the enemy little to learn that LUDO has been attached to SAGO, whereas he would like to know that the 24th Infantry Brigade has been attached to the 6th Division. A code is merely an abbreviation, and is used much in civilian telegraph cables. A cipher is a secret means of communication, usually operated by the use of a keyword. All wireless messages in time of war are put in cipher. The keyword should be changed frequently, as all ciphers can be deciphered in a certain time. Radio-telephony can, of course, always be picked up by the enemy, but in the army, radio-telephony is mainly confined to the smaller sets in which the signals are relatively weak.

R.A.F. ground signal communications is a matter in which Royal Signals plays a large part, as also in the signals of the air defence brigades. The R.A.F. undertakes its own wireless communications to and from the air, but the army must supply ground facilities for message-dropping and for picking up messages. The R.A.F. themselves are not partial to either of these as they take a pilot off his beat and may give away the position of head-quarters.

Air defence requires ground signal communications for two main purposes:

1. Intelligence. To give warning to air defence commanders at defended localities of the approach of enemy aircraft.
2. Command. To provide intercommunication for the command of the air-defence brigade.

Wireless is not required for this, telephonic communication and dispatch riders being more suitable. The teleprinter is also useful.

Such is a brief résumé of a few of the most important activities of Royal Signals. Nothing has been said of important side-lines such as G.H.Q. Signals, Corps Signals, and Signals on the lines of Communications, Railway Telegraphs, and many other units.

The work of a signal officer is interesting in the extreme and he has a dual responsibility; he must know what is required from the broad point of view of the actual operations, i.e. the staff point of view, and also from the narrower but no less important point of view of signals, i.e. the technical aspect. The first entails two things, a good knowledge of tactical considerations generally and very close touch with the staff. The second involves an intimate knowledge of what signals can do and even more what they cannot do.

In signals more than in most military activities good team work and the fostering of intimate relations between signals and the fighting troops is essential. Signals and sappers exist for the service of others and not vice versa, and they must help others all they can. Above all they should not be 'sticky' or continually raising small objections. This type is a real danger insomuch as he makes every one else 'sticky' and obstinate too.

CHAPTER VI

PROGRESS AND PROBLEMS OF FIELD ENGINEERING

As is suggested in the chapter on Fortification, it is impossible to separate fortification and field defence from one another, and there is no hard and fast line between the two. The object of both is the same—they are intended to increase the enemy's difficulties, to economize our own troops, and to give them the greatest opportunities to use their weapons to the fullest extent. They should also facilitate control and command. The failure of so many imposing fortresses throughout the ages can be mainly attributed to the loss of proper control and command, owing to deficient facilities for movement from one part of the system to another.

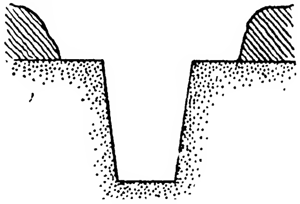


FIG. 8

In the laying out of field defences it must always be appreciated that a compromise is essential. It is impossible, for example, to combine an ideal position for concealment with one that gives the best situation for fire effect. A 'shell slit' gives the best personal protection, but no arrangement exists for protected communications. In the Boer War of 1899–1902 the Boers were given to digging just over the forward crest of the hills a system of shell slits whose cross-section was on the lines of that shown in Fig. 8, and they shot down the British troops as they attacked. When the bayonet threatened they scrambled out of their positions, ran a short way to their horses which were tethered on the reverse side of the hills, and they were thereby able to inflict heavy casualties and sustain very few, but the circumstances were exceptional.

The policy in the British Army has hitherto been to dig the fire trenches first and then, as time allowed, to get the communication trenches dug. This policy gave very little opportunity for concealment and is now discredited.

The doctrine on this subject, as laid down in Field Service Regulations, is as follows: 'For the infantry, concealment is the primary consideration both in order to surprise the enemy and to avoid his fire.'

How then is the concealment and subsequent enemy surprise to be achieved?

There are two methods whereby concealment is possible:

1. Positive concealment and deception.
2. Multiplicity, when several positions are dug, many of which are unoccupied.

(1) A weapon pit and its parapet is not a very large object, and in suitable country a great deal can be done to conceal it both from ground and air observation. The important part of the business is siting, and a good deal of time must be spent in training troops on right lines in this important matter upon which their own safety so much depends. It must be accepted that the proper concealment of a weapon pit adds considerably to the time required for its construction; at the same time effective concealment must be regarded as essential, and both digging and hiding are to be regarded as part of the same job. It is owing to this that fish-netting garnished with coloured raffia is an important article of store. Each Bren gun and anti-tank rifle is also provided with a 'spider and net', which can be used very effectively to hide the weapon and its gunner.

(2) Concealment by multiplicity takes much labour and time and is not feasible in cases where the time of preparation is limited, or when a position is only to be held for a short time. It is, however, the ideal, and must be the aim when circumstances permit.

Individual concealment can only be taught by practice, and the countryman is much more apt at this than the townsman. Everyone in the army must know something of the use of shadow and light. Incidentally, the soldier's anti-gas cape can be quite easily painted in camouflage effect. It must be appreciated that there is no such thing in nature as straight lines or regular spacing and this must be avoided at all cost. Artificial cover if used unskilfully is worse than useless—a bush in the middle of a ploughed field attracts attention at once.

Camouflage is now a subject of the highest importance and it is much more than concealment. A hare lying in a furrow of a ploughed field is perfectly camouflaged by nature. Though in reality it is visible, it is not distinguishable. Deception is the essence of true camouflage, and it is the camera that must be deceived. This is far from easy as in all armies a very systematic study of air photographs is an important branch of intelligence duties.

As regards trench systems the present policy is to dig a good deal of what are known as 'crawl' trenches. These are 18 in. deep and are the quickest-dug trench that enables a man to get along under cover from view. The width is the standard 3 ft. 6 in. and it should look from the air exactly like the standard trench 3 ft. deep. It is, of course, true that with only half the amount of depth excavated, the parapet is not bullet-proof; moreover, some of the excavated earth must be spread to full parapet width to deceive the air camera. In good earth an unskilled soldier can dig 5 yds. of 'crawl' trench in a 4-hours' task as against only 2 yds. of standard trench. Crawl trench gives 2 ft. 6 in. cover from view, and a system constructed with a good deal of this gives the enemy no opportunity for discovering the organization of the defence. The problem of the inclusion of machine guns and anti-tank weapons in the defence is also simplified. It is most important that digging should be done in an irregular manner, so as to afford no clues to the organization of the defence. It must be accepted that for an effective system a vast amount of digging is inevitable, and continual forethought is essential if unnecessary work and waste of time are to be avoided.

There will be many occasions in open country when there is little chance of concealment from the air. The Englishman is too apt to judge a situation instinctively from his knowledge of the typical English countryside.

Although concealment is impracticable, it should still be possible to prevent the enemy from identifying what he sees or what he photographs. Special care must be taken with transport, and under no circumstances should vehicles move in groups from which the type and size of a unit can be identified.

Stress must be laid on the matter of drainage in constructing trench systems. When a system is being dug in dry weather in summer it is quite easy to forget the changes that wintry conditions involve. Natural drainage must be the aim, as sumps and drainage pits are, at the best, unsatisfactory alternatives. In sandy country, drainage problems may not be so serious, and the principal problem will be the revetment of the sides of trenches. In country where the natural angle of repose of the earth is small there is a tendency to construct trenches with parapets that are not bullet-proof.

The matter of anti-tank defence has been dealt with in another chapter, but it cannot be too much emphasized that this consideration is of vital importance in the construction of field defences.

Opposed River-crossing. For several reasons the problem of the river-crossing is now more cogent than at any other time in the history of warfare. Increased weights of military equipment make heavier bridges necessary, and heavier equipment means that more men are necessary to handle it. The increased mobility due to mechanization has added to the number of rivers that may have to be crossed in a given space of time, so that more bridging equipment is required. Moreover, in the absence of an amphibious tank, the river line or marshy ground is the obvious anti-tank defence, so that this type of obstacle is widely used by the defence.

In the past much reliance has been placed on bridging expedients, using extemporized methods roughly suited to the particular problem. In the war of 1914-18, for example, the British Army had only one type of mobile bridging contrivance—the pontoon equipment. Other armies had made more specific provision for heavier loads, railway bridges, and the like, and the French Army had a useful girder bridge known as the Pont Henry.

The Germans were not so well off, but their Austrian allies had suitable equipment of a somewhat similar type which was widely used on German account. The drawback of extemporization is that of time—the extemporized bridge takes many hours to construct, whereas it may be essential to get across in as many minutes, and it is now generally recognized that the only effective solution is provided by standard equipment, which must be of varied types suited for the varying loads. Over and above this a certain amount of equipment must be provided on the lines of communications for bridging expedients, such as steel cube piers which can conveniently be made up into crib piers, and also tubular scaffolding which is similar to what is so much used in building work. Light pile-drivers are also likely to be useful.

The first phase in an opposed river-crossing is the passage of assault troops to seize a footing on the far bank. Their duty is then to advance to a distance that will enable the bridge-builders to be protected at least from rifle and machine-gun fire, i.e. to establish a protected area around this vital spot. This operation is called the establishment of a bridge-head. Until the amphibious tank materializes the passage of infantry to secure the necessary bridge-head must constitute the initial phase of practically every opposed river-crossing. It is a phase quite distinct from those that follow, and upon its success will depend that of the whole crossing. For many years the British Army has had the Kapok assault bridge (Fig. 9) as part of its equipment for this task. Kapok is a tropical product bearing some resemblance to cork, and the Kapok bridge consists of light floats carrying duck-boards which infantry parties launch across a river in suitable places. Kapok is intended for crossings not much over 100 ft. in width and is not suited for swift-running rivers. One bay of this bridge weighs 1 cwt., and a carrying party of three men per bay is required, with an allowance for casualties. A bay is 6 ft. 6 in. long. It has long been recognized that Kapok crossings are very vulnerable, easily recognized from the air, and easily broken. They constitute what is in many respects a dangerous artificial defile. For the initial crossing the essentials to success are careful reconnaissance, good organization, and the ability to cross at a number of places quickly and inconspicuously. Kapok equipment may suit for this in places, but its adequacy under many circumstances is questionable, and it is now supplemented by a number of portable boats known as infantry boats. There are two types of these: one is the reconnaissance boat, a flimsy affair made of rubber and capable of carrying two armed men. It is mainly intended for use by scouts, who paddle it across the stream and leave it on the far bank.

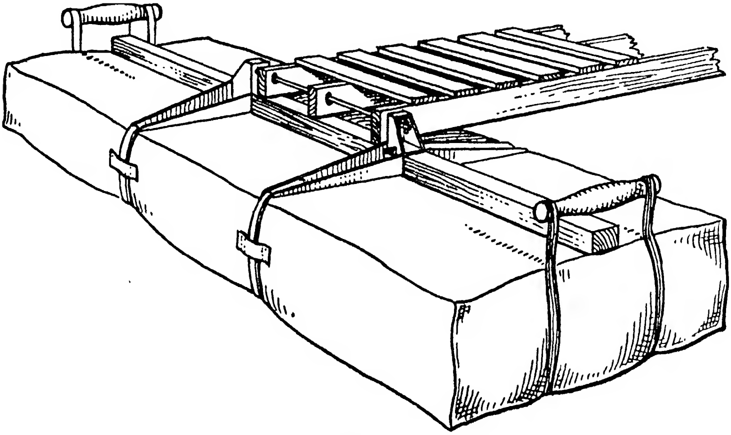


FIG. 9

The assault boat is a more substantial affair. It is a collapsible boat capable of carrying nine armed men, of whom two are rowers. These boats are carried by the Divisional Field Park Company, which is the sapper unit at divisional head-quarters, and they are issued to the infantry when required for use. The Kapok equipment, together with these boats in adequate numbers, provides as good a solution as can be expected for the initial problem of the assault crossing, at any rate as far as the most forward troops are concerned. The assault troops having established a bridge-head, the next problem is the passage of the close support weapons and vehicles required for their support. It must be appreciated that infantry cannot carry on for more than a limited period without their trucks, Bren carriers, and the somewhat extensive column of vehicles that is comprised in the infantry battalion. For their conveyance over a water-gap the folding-boat equipment is available. This equipment, a limited amount of which is available with the Field Park Company and a good deal more with the Corps Bridge Company, is shown in Plate 13, in which a folding-boat bridge is under construction.

These boats, which flatten out so that 3 boats can be carried on a 4-wheeled trailer, are 22 ft. long. A single boat can be used without crowding for 16 armed men in addition to the commander and the crew of 4, and it may be a useful addition to the lighter equipment for the assault crossing. Two of these boats can be combined to form what is called a tracked raft, which will carry a useful load. The tracked raft is end-loaded, and is so called as two tracks parallel to the boats are used in place of a roadway. Plate 13 gives an example of this. For rather heavier loads, two boats can be arranged as a decked raft, in which the roadway of the raft is at right angles to the boats, but this involves gunwale loading, and landing-stages are required to get loads on and off. The tracked raft is, however, capable of carrying all of the equipment of an infantry battalion, and a sub-section of well-trained sappers can construct one of these very quickly by day and fairly quickly by night. These folding boats are, however, not very portable, and each of them requires a party of some sixteen men for their carriage and launching. The actual launching of the boats can be done almost noiselessly, but it is not so easy to get the troops into the boats silently. The decked rafts can be superimposed to form a bridge, and if a good deal of transport has to be passed over, this is of course far quicker than ferrying. The selection of the site for such a bridge is a matter of a good deal of importance, as the approaches often take longer to construct than the bridge itself.

The damage caused to a folding boat by a direct hit of a bullet is not serious, but ricochets are capable of making large holes in the sides of the boat. Field company and field park sappers are trained in methods of plugging or of otherwise repairing such holes. In the folding-boat equipment are included what are called trestle units, whereby the parts of rivers near the shore can be bridged. This equipment provides the wherewithal to take forward fighting units and their equipment over rivers, but this does not solve the whole problem. It may often happen that gaps over relatively small rivers have to be bridged where hitherto existing bridges have been demolished, or where little or no water is present, and no water-borne boat or pontoon can then be used. For this purpose what are called small box girder-bridges are available (Fig. 10). In these bridges the same principle is used as in the meccano toys with which small boys make all kinds of articles. The bridge is primarily intended as a rapid means of bridging fairly wide gaps. The bridge is made of 2 girders each built up of box sections, with tapered end-sections, called hornbeam sections, which are a little longer. The material of the girders is high-tension structural steel with electrically welded joints. They are joined together by steel dogs. These bridges can be launched by a cantilever method with a launching nose or by a derrick and preventer tackle.

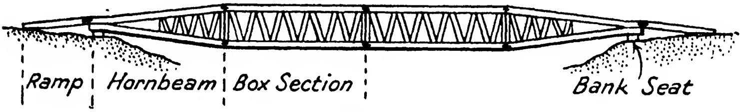


FIG. 10

The types of equipment so far described fulfil the army's requirements for operating in country typical of English inland counties, where only small streams have to be crossed. When rivers of any magnitude have to be crossed the service pontoon equipment has to be used. This equipment is necessarily both heavy and bulky, as it must be capable of taking the maximum load that is included in the field army. It is carried in units called Bridge Companies, and as such units occupy a great deal of road space they are kept very much in the background until such time as they are required. It is possible to alter the spacing of the pontoons according to the nature of the loads, the pontoons being brought very close together where the heaviest loads have to be supported.

The Service Pontoon (Fig. 11) is a flat-bottomed boat which is completely decked over, being divided by bulkheads into two compartments. Each pontoon weighs over half a ton and two pontoons are coupled together by strong steel couplings. It can be readily imagined that such pontoons are not easily handled. In the main they are composed of a special form of plywood possessing the advantage that simple punctures made by ingoing rifle bullets tend to close up quickly in the presence of water.

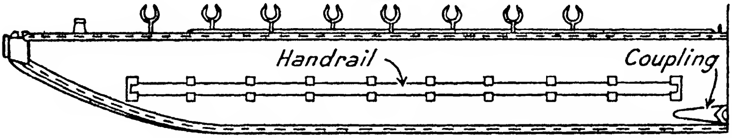


FIG. 11

Having launched and joined together the two halves of the pontoon the superstructure has to be erected. This consists of steel road-bearers which are joists of high grade steel. On this are laid the planks (called chesses) which are made of Oregon pine. In order to provide for the first part of the bridge near the shore where the pontoons would not be water-borne and therefore liable to damage by the loads, steel trestles are provided. Two jacks are supplied for each trestle, and by this means the transom carrying the load can be lifted or lowered. This would be essential in a tidal river.

The pontoon equipment may be used to form what is called medium bridge, and in this case fewer pontoons in a given length of bridge are required. If the heaviest loads are to be carried the pontoons are spaced closer together and this is then known as heavy bridge. In heavy bridge the pontoons take up a good deal of the water-way.

It is often necessary to form a gap in a floating bridge to allow river traffic to pass through, and this can be done by working one of the rafts downstream. Such procedure is known as 'forming cut'. The pontoon rafts are heavy and inconvenient to row and outboard motors are sometimes used.

Mechanization has done much for the field engineer in supplying him with power equipment for various purposes. Many factors have to be considered in the choice of power tools for a field unit. Their number must be strictly limited and it is essential, therefore, that they combine lightness with a wide field of employment. Robustness is essential, and as military work usually involves several jobs of a scattered nature, the power employed must be flexible. At first thought, electrically operated tools would seem suitable—actually this involves a number of small generators and motors and the weight involved is too great. Compressed air is the medium chosen—it is specially suited for the boring and percussion tools which are above all required for demolitions, making loop-holes in walls of houses, and similar tasks. The compressor is a heavy and bulky machine, but it is found possible to provide one truck with its compressor and a complete set of tools for each section of a field company. The ideal is for every lorry to become a source of power for operating drills, saws, pumps, &c., and there is reason to think that a power take-off with a flexible drive will eventually be achieved.

Mechanization also helps the field engineer in water-supply arrangements. Operations in a thickly populated country like Great Britain, where supplies of water are widespread, tend to dwarf the importance of this in other theatres of war. It is not too much to say that the success or otherwise of a whole campaign may rest on this factor alone. In the war of 1914-18 sapper field companies had merely a solid but clumsy and somewhat inefficient hand-pump capable of lifting water some 25 ft. vertically and delivering it a further 35 ft. Well-sinking units had to be formed in rear areas to supplement this very inadequate provision. The problem of water-supply equipment is to find a single type capable of dealing with both shallow and deep sources. A mechanically driven pump is now available using a flexible drive between the pump and the engine, which can be lowered when the source of water is deep. It is not often that water has to be pumped more than 100 ft., and when wells are of greater depth, special equipment outside the range of ordinary sapper field units must be obtained.

The construction of shelters and dug-outs is more important than ever in modern warfare. It is important to decide in the first instance what degree of protection is required. Three grades of protection can be provided:

1. *Shrapnel or Splinter-proof.* This merely protects the soldier against shrapnel, machine-gun bullets, and small splinters. Shrapnel is little used nowadays, the complication of the bursting fuse being undesirable and the high-explosive shell having a more devastating effect. Splinter-proof protection can be provided in a relatively short time as it only requires about 2 ft. of earth, with a burster-course hard enough to detonate the explosive fuse.

2. *Shell-proof Protection.* This is proof against shells from field guns or howitzers up to 6 in. To give this degree of protection 35 ft. of earth, or 30 ft. of clay or 15 ft. of hard rock is required. Such degree of protection would be attempted when several days are available for the preparation of a position which is intended to be held for a considerable time.

3. *Heavy Shell-proof.* Protection is then secured against 8-in. shells, heavy trench mortars, and against direct hits by even heavier shells. Such degree of protection would only be attempted in protracted defence, as it requires 40 ft. of protection in ploughed land; only mined dug-outs meet this case unless reinforced concrete is available, and then a thickness of 4 ft. of this material is required. Concrete for military purposes must always be of the quick-setting variety.

A higher degree of protection than this comes within the province of fortification and would not be attempted in the field. In general, nearly 60 ft. of earth or 6 ft. of reinforced concrete is required to provide full protection from 12-in. shells.

It is important to realize that it is useless to attempt to get from one degree of protection to another. If, for example, having aimed at splinter-proof protection, the degree of cover is increased, it is only too likely that instead of being protected the inmate of the dug-out may get buried alive.

Shell-proof protection is normally obtained by what is called 'cut and cover' methods: the necessary hole is dug in the ground and the necessary framework, well-stayed in all directions, is inserted. A roof made up of steel joists carried on a timber frame is a possibility for this, but much bracing is required, and a better device uses the principle of the arch, rather on the lines of the Anderson steel shelters that the British government has distributed so widely in threatened areas. Different types of these corrugated steel shelters are supplied in various sizes as an article of military store.

The third type of protection involves tunnelling, and this type of accommodation is provided for head-quarters of fighting formations, sub-ways, dressing-stations, and so on. These deep dug-outs must have two entrances, and both drainage and ventilation must be very carefully considered. Gas curtains must always be provided. One of the biggest problems in such work is the concealment of the spoil evacuated. The amount of this is considerable, and unless a scheme of disposal is thought out beforehand, conspicuous dumps of earth are certain to show up to the enemy. One method is to work the spoil into the parapets of dummy trenches in the vicinity.

It is sometimes necessary to depend upon buildings for protection, and although this is better than nothing it is not ideal. It is possible to increase the protection provided in the first instance by building sandbag walls and strutting roofs. If a cellar is available, fair protection is obtained when the roof has been well shored up by stout timber, as the walls and roof of the house act as bursters. Steel shelters placed well back from the walls and covered with sandbags or concrete give good medium protection. A.R.P. considerations alone have resulted in the widespread use of sandbags, concrete, and other revetting materials. It is unfortunate that the average A.R.P. worker knows very little on the subject, and the one and only solution seems to be sandbags, many millions of which have been employed. Moreover, the word itself is unfortunate, as they are almost always filled with expensive sand instead of inexpensive earth, rubble, or shingle. It is forgotten that sandbags placed outdoors, unless specially treated, only last a few months and constitute an expensive form of protection. A casual walk round any town in England in the autumn of 1939 would show the lack of skill with which the work had been done. Rarely was the 4 to 1 slope inwards towards the top, which is so important, attempted. The bags were almost invariably too full, nor was the proper 'bond' with headers and stretchers attempted, with the joints broken in different places. In many places in the city of London itself the bags were to be seen in shapeless heaps, whose main use was as divans or claw-sharpeners for the office cat.

Some attempt has been made by the Air Raid Committee of the Institution of Civil Engineers to work out on scientific lines the effect on buildings of high explosive. It is well known that detonation velocity exercises a controlling influence on the intensity of the blast, but as the distance from the explosion increases, the velocity of the blast approximates to that of a sound wave in air, i.e. 1,100 ft. per second. The range within which the direct local effect of the explosion is the important factor is strictly limited, varying from about 25 ft. for a 500-lb. bomb to a distance of 65 ft. for a charge of 1 ton of high explosive, representing a 3,000-lb. bomb. The importance of blast is that it can transmit a destructive force far outside the range of the local effect. Blast is transmitted in the form of a wave, and the duration of the pressure phase is as important as the intensity. The positive change of pressure above atmosphere is usually much greater than the negative since the actual pressure can never fall below zero. This blast effect on a target approximates to a sudden push followed at a short interval by a sudden pull. Often the pull is the deciding factor that causes rupture. If the duration of the push is sufficiently long, the vibration set up in the target may be such that when the following pull arrives, the target is already oscillating in sympathy with it and the effect is then considerable—in other words resonance has occurred. The natural period of vibration of the building is therefore a matter of importance. Structural targets of high frequency are more likely to be ruptured by blast than those of lower frequencies.

Another matter of importance in connexion with bombs is penetration. Against personnel in the open, or fairly flimsy buildings, bombs are more effective if the high-explosive filling is considerable compared with the total weight of the bomb. The present standard type of bomb is of cylindrical rather than of stream-line shape, as tests have indicated that the resistance encountered in flight by well-designed cylindrical bombs is no greater than that of the more expensive stream-line type. When bombs are dropped from a great height they attain a terminal velocity of about 1,500 ft. per second. It is important to note that such bodies as sand are relatively more effective against splinters of high velocity than against those of low velocity. Thus at 350 ft. per second the resistance to penetration of sand is about one-third that of timber, whereas at 2,000 ft. per second the resistance of sand is rather higher than that of timber. Obviously, therefore, it is best to arrange for the splinters to penetrate the sand first, i.e. sandbags should be put outside and not inside a wall. Sand gives special protection in the immediate neighbourhood of an exploding bomb. Sapper officers in their professional capacity must know a good deal about the resistance to penetration of various materials from bullets, shell-splinters, &c. It should be noted that greasy clay has very slight resistance to penetration, and rifle bullets will penetrate a clay parapet which is less than 5 ft. thick.

It is sometimes suggested that engineers have been so much helped by mechanization that their numbers can be materially reduced, without serious handicap to the other arms of the service whom they are intended to assist. No greater mistake could be made. The provision of vehicles for carrying engineer formations from place to place (one vehicle to each sub-section) has been a great benefit—in the war of 1914–18 the greater part of sapper formations were expected to 'foot-slog', and in mobile operations they were already seriously fatigued when their day's work had only begun. The power-tools have also been helpful to a degree. But mechanization has not only been a fairy godmother in saving labour; it has been a hard task-master in providing work as well. It has already been seen how much more work the progressive increase in the weight of military bridges involves. In addition, greater speed of movement has involved greater obstacles to movement. The increased efficiency of air attack alone is likely to provide the sapper with much more work. Nothing has been said, either, about the work that falls on sapper units in services on behalf of our own air formations. All the R.A.F. groundwork has to be carried out by the R.E., and the clearance of the land for their essential aerodromes and landing-grounds is by itself a considerable task.

In general, the modern trend tends to make demolition easy and clearance difficult. Special equipment now exists for cratering arterial road, but no gadgets are supplied for filling in the craters, and time-honoured methods involving the use of the pick, the shovel, and the wheel-barrow are alone available. Blocking-parties on open flanks, erection of tank obstacles, elaboration of hasty defences, supply of engineer stores for the other arms, involving little factories, saw-mills and the like for the provision of duck-boards, A frames, and other revetment stores—all these and many other jobs of all kinds, impose more duties on sapper formations under modern conditions than ever before, and although the infantry battalion has now its pioneer platoon for the more obvious jobs, 'Sapper Shovel' is likely to be in demand more than ever under mechanized conditions.

Sapper requirements vary greatly in different circumstances. The ordinary allotment for a division is three field companies. During active operations it is quite possible that six such units may be required on a divisional front, and the tendency is to treat the sappers in much the same way as the gunners. With the latter, army formations are available for reinforcement when artillery support is specially required, and it is likely that army field companies will have to be available to reinforce the ordinary divisional quota of sappers. The sapper section (4 sub-sections) is now larger than has ever formerly been the case, and very serious responsibility devolves upon the subaltern in charge. Furthermore, any sapper N.C.O. may now be required to assume a definite command on an independent task, and the training must be equally thorough if such responsible work is to be undertaken in the adequate manner that the Corps of Royal Engineers has the right to expect.

CHAPTER VII

DEMOLITION AND MINING AND SOUND LOCATION

WHAT is really the most remarkable feature about explosives is the absence of important changes in recent years—so much so that it would seem that finality has been reached in all but details. The gunpowder that was used in the war of 1914–18 in hundreds of thousands of tons—mainly for important subsidiary purposes such as the bursting charge in shrapnel shells—was in its essence the same as that used at the battle of Crécy; similarly, the cordite that is used to-day to propel the bullets of our Bren guns and our anti-aircraft shells is of similar composition to that employed in the British Army in the nineteenth century.

Explosions are due to the sudden change of comparatively dense matter in the solid or liquid state into an enormously increased volume of hot gas occupying many thousands of times its original volume. The original solid or liquid may be a mechanical mixture of substances capable of chemical reaction, or it may be a definite chemical compound of a relatively unstable type. Gunpowder is the best example of the former, and the British service gunpowder has the following composition:

Saltpetre	75 per cent.
Sulphur	15 ,,
Charcoal	10 ,,

Gunpowder can only be set off by heat, and the action takes a small but appreciable time, producing a considerable lifting but very slight shattering effect. For centuries gunpowder was the only explosive known, and the suddenness of its action was modified by varying the size of its grains, these being of a considerable size when its use was desired as a propellent to push a projectile out of a gun or rifle.

Nowadays, gunpowder, though of considerable use, is mainly required in the army for subsidiary purposes such as the core of safety fuse, as a primer for igniting cordite cartridges, and in shell fuses.

By far the most important explosives of to-day consist of a single comparatively unstable chemical compound. An example of a relatively harmless explosive of this type, which can be easily made in the laboratory by mixing an alcoholic solution of iodine with ammonia, is nitrogen iodide. This is so unstable that when completely dry it can be set off when a fly walks on it, a large volume of nitrogen and iodine vapour being produced with a sudden crack. Such an explosive would be far too unstable and not sufficiently powerful for everyday use.

Another very sensitive class of explosive is the fulminate group. Silver-fulminate is the constituent of Christmas crackers, and mercury-fulminate is much used in the service for detonating fuses.

The main military explosives can only be set off by shock, such process being known as detonation. This shock sends a disruptive wave sweeping through the mass of the explosive with enormous rapidity. The speed of this wave is a fairly accurate measure of the shattering nature of the explosive. In guncotton, used in the service for cutting steel, the velocity of the detonating wave is about 4½ miles per second, whereas in ammonal, which is in use for mining purposes and where greater shifting and less shattering effect is required, the velocity of the detonating wave is no more than 2½ miles per second.

The discovery of high explosive made a considerable change in warfare—Nobel, a Swede, was a pioneer in this respect with his discovery of the explosive use of nitro-glycerine, until then used merely as a stimulating medicine in heart ailments. Nitro-glycerine is an oily liquid; in Nobel's time it was continually leaking from its container and causing accidents, and one morning in 1865 Nobel's plant in Norway soared skywards. After this several countries passed laws forbidding the use of Nobel's 'soup', but by mixing three parts of it with one part of a light absorbent earth found in Germany and called *Kieselguhr* he made stuff like putty which is much safer. This is dynamite.

Nobel died in 1896, and it is said that he spent his last minutes chuckling because they prescribed nitro-glycerine for his failing heart. He left his fortune amounting to nine million dollars to found a peace prize.

High explosive revolutionized warfare in two directions —it made for invisibility on the battlefield owing to lack of smoke and it enabled shells to move farther and to penetrate much more deeply than heretofore. When high explosive came into use, all previously existing fortifications were rendered out of date, though it was possible to do something in the way of renovation by adding protective layers of reinforced concrete.

Dynamite is even more violent than guncotton, its velocity of detonation being 5 miles per second, but it is not suitable for military purposes for two reasons—it can be detonated by flame as well as by shock, and it freezes at 39° F., when it is both sensitive and uncertain in its action. Nitro-glycerine explosives are sometimes modified so that they freeze only at a good deal lower temperature. Polar gelignite is an example of this. Blasting gelatine consists of about 7 per cent. of collodion cotton dissolved in nitro-glycerine, and a stiff jelly is formed which is comparatively safe to handle. It decomposes after long storage, especially in hot climates. Guncotton, which (except in large quantities) burns and does not explode if ignited, is a far safer explosive.

It is of interest that cordite, the service propellent, a relatively slow and pushful explosive, is a mixture of guncotton and nitro-glycerine, two of the most violent and shattering explosives known. Cordite contains 65 per cent. guncotton, 30 per cent. nitro-glycerine, and these are incorporated together by 5 per cent. vaseline. May this not be the explanation of the rather unexpected fact that the two detonating waves of different frequency of the two constituents produce interference, and a relatively slow velocity of detonation is thereby produced? Heterodyne reception in wireless and 'beats' in acoustics are examples of this phenomenon.

Guncotton is used in the army in 1-lb. slabs whose length is twice their breadth. The slabs are kept damp with some

20 per cent. of their weight of water, which renders them safer to handle and increases their explosive effect. Wet guncotton is non-inflammable and so stable as not to be detonated by the impact of a rifle bullet. It would be difficult to detonate it by a small fuse alone, and into a tapered hole in the guncotton slab is put a 1-oz. 'primer' of dry guncotton. This primer itself contains a small hole, and into this is put the service No. 8 detonator, which is a small tube containing about 2 grammes of mercury-fulminate (Fig. 12). Into the open end of this tube is placed a length of safety fuse. This safety fuse contains a column of fine gunpowder and it burns at about 2 ft. a minute, thus giving time for getting away after the end of the fuse is lit (Fig. 13).

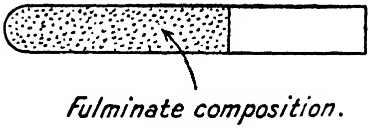


FIG. 12

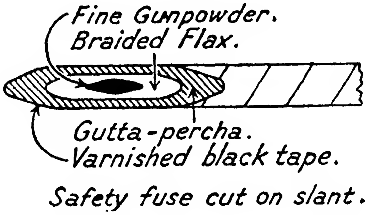


FIG. 13

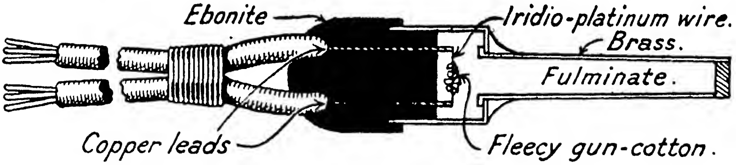


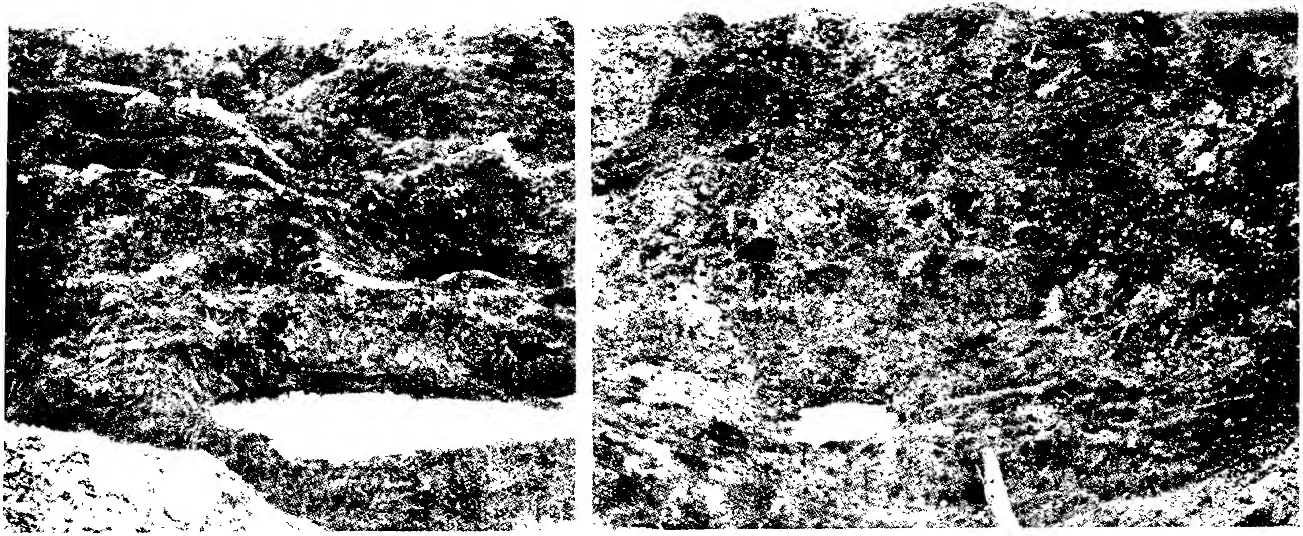
FIG. 14

If several charges are to be let off simultaneously, the charge is often fired by electricity, when an electric detonator (Fig. 14) is used. A small magneto, called an exploder, supplies the necessary current, but the accumulators of a motor-car are equally suitable.

PLATE 16

Vimy Ridge—Entrances to Subways

(By permission of the Institution of Royal Engineers)



Montreal Crater (1917)

(By permission of the Institution of Royal Engineers)

Ammonal, the service mining explosive, is a grey powder and is about three times as powerful as gunpowder. It is composed as follows:

Ammonium nitrate	68 per cent.
TNT (obtained from coal tar) . .	15 „
Powdered aluminium	17 „

One of its drawbacks is its tendency to absorb water, which greatly impairs its action. When more than 8 per cent. of water has been absorbed it will not detonate at all, and if it is to be kept in position for a long time it must be stored in damp-proof tins. These can be detonated by a primer, detonator, and safety fuse, but it is more usual to wind round the tins 'Fuse Instantaneous Detonating' (always known as FID) consisting of a lead tube filled with a yellow high explosive called Trotyl. FID can be used to initiate a number of charges simultaneously when firing by fuse.

Various high explosives are used commercially, but are rarely altogether suitable for military purposes when enemy shells and the danger of fire complicate matters.

The greatest recent improvement in military explosives has been the supply of a plastic high explosive which has all the advantages of dynamite and none of its disadvantages. For the intensive destruction of arterial roads or railways in a withdrawal this explosive is ideal. It is also much in request for anti-aircraft work, where the shell fragments normally fall on home territory, so that efficient fragmentation of the bursting shell is essential. A matter of importance in the use of high explosive is the resistance offered by air. It is a commonplace that air offers little resistance at low velocities, but when bicycling, for example, against a wind, air resistance becomes very appreciable. When the speed in question is of the magnitude of a detonating wave, the resistance offered by air is roughly that of steel and is usually calculated as such. If, for example, slabs of guncotton cannot be put in immediate contact with a girder owing to the presence of rivet-heads, it is necessary to assume that the intervening air has the same strength as steel. Guncotton can cut steel of about its own thickness, and a single 1-lb. slab effectively breaks a heavy rail.

A plastic explosive such as dynamite can be made to fill every nook and cranny of a bore-hole, and this is one of the reasons for its suitability for blasting purposes. It is sometimes said that high explosive 'strikes down', and this is due to the enormous resistance offered by air to sudden change. When dealing with a low explosive like gunpowder the line of least resistance is through the air, and when using gunpowder in a demolition it is necessary to use earth, sandbags or the like as 'tamping' in order to prevent a blow-back and an unsatisfactory job.

The demolitions that may be carried out in modern war bear no relationship to what was done in the past. Royal Engineer units are now supplied with special equipment whereby small chambers known as camouflets are blown in arterial roads, allowing a much larger demolition charge to be inserted. A heavy charge of ammonal is then placed at a depth of about 6 ft. and a huge crater in the road is thereby produced. A sapper unit can blow scores of such craters in a day. It may be noted that no equipment is available for repairing such damage, and it is therefore obvious that the delaying action of rearguards is far more considerable nowadays than heretofore. Blister gas may come into this picture as well, and there is little doubt that mobile blocking-parties can be an important factor in a retirement. The power-tools with which all field engineering units are supplied enable mined charges in abutments of bridges, piers, and walls to be quickly laid. Delayed-action mines are another device of value for this purpose, and a special article of store is now supplied whereby 'booby traps' can be quickly and effectively laid. The Germans, always to the fore in any unpleasantness, were very clever in the war of 1914–18 in placing explosive charges in such places as to be detonated by some routine act such as the pulling of a chain, or treading on a loose board in a floor; had they exercised greater imagination, a quality in which they are often lacking, such devices would have been even more effective. In the Saarbrücken region they excelled themselves by placing contact mines under dead bodies.

For cutting barbed wire, a difficult and often important undertaking, a form of portable charge known as a Bangalore torpedo is often used. It consists of a thin pipe some 2½ in. in diameter filled with explosive. Its extremities are closed with wooden plugs, through one of which a detonator is inserted. The torpedo, which should be equal in length to the width of entanglement to be cut, is laid in the wire and exploded at a suitable moment.

MILITARY MINING

Military mining goes back far beyond the discovery of gunpowder and is one of the oldest applications of engineering to the art of war. The Romans were expert at it.

When gunpowder was first discovered, underground attack became more common, for mining was a far more direct and effective application of explosive than the crude artillery that was first used. As with most new discoveries, the professional soldiers—not altogether without reason—were somewhat scornful of its value. Froissart, in his original account of the battle of Crécy, merely mentions that 'the English remained still and let off some bombards that they had, to frighten the Genoese'.

Right until the introduction of rifled guns in the American Civil War, mining was the only satisfactory means of effecting a breach in masonry fortifications. At the siege of Sevastopol some 200,000 lb. of gunpowder were consumed in mine galleries.

It is significant that mining was considerably used in the Russo-Japanese war of 1902–4, but so much were the various staffs imbued with the idea of war as an intensely mobile affair that this seems to have excited little interest.

It was the Germans who first started mining in the war of 1914-18 and by December 1914, mines had been blown under the Allied trenches in many sectors. British sapper officers had had very little training in mining, and owing to this it was quickly appreciated that to cope with the menace officers and men had to be recruited from those who had been trained in underground work in civil life. This was the genesis of the Tunnelling Companies, R.E., and within less than two years 25,000 troops were employed in the British Expeditionary Force alone in underground operations. The enemy could not afford to detach so considerable a part of his national mining personnel as this, nor did underground warfare develop on so large a scale on the French front. Mining figured only to a very minor extent on the Italian front and in the Dardanelles campaign.

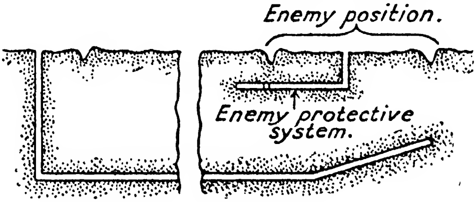


FIG. 15

The technique of mine warfare is that one side tries to get under the enemy's surface defences by offensive mining. This is opposed by countermining, which usually takes the form of burrowing under the enemy workings and blowing a charge to destroy his galleries.

The photograph (Plate 15) shows a small mine operation east of Ploegsteert Wood in 1915, when two mines, each of 2,500 lb. charge, successfully dealt with an enemy salient enfilading the British trenches. Other photographs (Plates 16 and 17) are of the entrances to the subways and a crater at Vimy Ridge in 1917.

Success in mining depends very much on surprise and speed of working. Silent working is of the utmost importance, as is good underground listening. It was found that professional miners worked far more quickly and silently than sappers.

Figs. 15 and 16 gives diagrammatically some idea of the technique of deep offensive mining. It will be noticed that it is better to drive a vertical shaft at the start rather than to get into the ground by an inclined working.

By degrees, as the war of 1914-18 proceeded, the British had in most cases gained control of the underground situation. In 1916 the Germans started to withdraw their mining personnel, as they were more needed at home. Moreover, the new system of fighting with lightly held advanced trench-lines rendered mine warfare less effective. Actually, the biggest mining operation in the history of war was carried out by the British in their attack on the Messines Ridge on 7th June 1917, when over one million pounds of high explosive was discharged on a front of 10 miles. Although causing a good deal of alarm to our own assaulting troops, some of whom had not been warned of the presence of mines on their front, these mines caused a considerable paralysis of the enemy defence, and General Ludendorff in his *Memoirs* attributed the German reverse on this occasion to our underground activity.

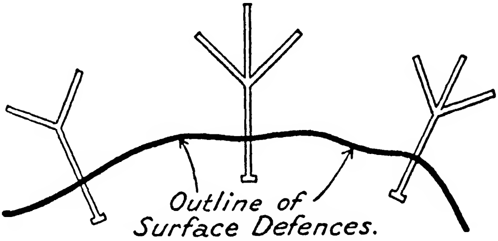


FIG. 16

The question naturally arises as to what extent mining is likely in future operations, and there is little likelihood that it will be adopted on the scale that was attempted in the war of 1914–18. Miners are very precious in time of war, and the casualties that were inflicted were rarely commensurate with the expenditure of personnel, material, and time. It is, however, as certain as anything can be that static periods are inevitable in wars between powers of comparable size. Moreover, fortified works are at present in many cases so strong that it is highly unlikely that they will be reduced by tank assaults, however well supported. Furthermore, the moral effect of mine explosion and earth tremor is considerable even against the stoutest troops, and the equipment required for mine operations is simple and easily improvised. When not wanted for mine operations, mining personnel is always useful for digging deep dug-outs, which are so essential nowadays, and there is little doubt that mining will feature in static phases of warfare whether now or in the future.

Mine warfare called for a good deal of specialized research in various directions. Very little was known about the size of charge required to produce a given underground effect, and a good deal of information was amassed in 1914–18 which is of use not only in connexion with mining but also in such matters as A.R.P. Complete trials were carried out by the experienced staffs of the mining schools on the properties of ammonal, amatol, and sabulite, and tests were made of the effect of charges varying from 3,000 lb. downwards. Experiments on the sympathetic detonation of explosives were also carried out.

Of the various branches of military mining, mine-listening is one of the most important, and has its counterpart in a very different field of military activity in the location of enemy aircraft. Whereas the principles involved are simple, the practical complications are considerable.

Sound is due to longitudinal vibrations travelling at a definite speed depending on the nature of the medium, but whereas it travels through the air at about 1,100 ft. per second, its velocity in the ground varies from three times to nine times this amount according to the nature of the soil. As a result the sound waves are largely reflected at the surface dividing the two media and these are almost entirely separated acoustically.

On the other hand, the passage of sound vibrations from the earth to solid or liquid substances in close contact with it takes place with very small loss. Hence, if an iron bar is driven into the ground and the ear applied along its free end, the bar will collect sound vibrations over a large area and hearing will be improved. A more sensitive device can be arranged by burying the base of a bowl filled with water in the ground and immersing the ear in the water. These two devices constitute primitive listening apparatus, and all mine-listening instruments collect sound vibrations direct from the earth on these lines.

The stethoscope method—whether used by the doctor to listen to noises in human lungs or by mine-listeners in locating hostile tunnelling—is a practical application based on the combination of the above principles with the property possessed by an enclosed column of air of accurately transmitting sound-waves. In the military type the water-bowl is replaced by a water-bottle (Fig. 17), to the neck of which the stethoscope tubing is attached. Even the most minute vibrations of the water will be conveyed to the ears, provided that the columns of air within the tubes form the only exit from the bottle. The bottle should be completely filled with water and placed on the ground. It constitutes a very sensitive listening apparatus and a useful makeshift in default of more suitable equipment. Water is, however, a substance in which the sound-waves are much distorted in transmission, and noises so transmitted are hard to identify. It is found that mercury gives a far more accurate and faithful reproduction of sound waves, and this is the medium used in the geophone.

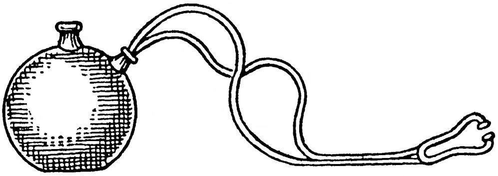
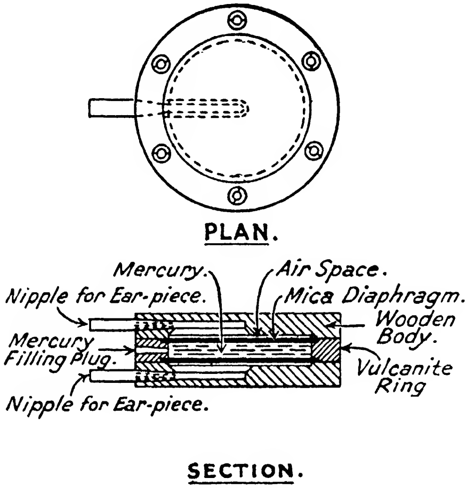


FIG. 17

The action of the geophone is identical in principle with that of the stethoscope water-bottle, but mercury enclosed between two mica diaphragms replaces the water. The geophone (Fig. 18) is simply a hollow wooden circular box some 3 inches in diameter—usually called the pot. It is divided into three horizontal compartments by two mica disks. The two outer compartments contain air, and connect by air to the ears of the observer. The horizontal space between the mica disks is filled with mercury. When the box lies on the ground it is shaken by sound pulses coming through the earth. The mercury has so much inertia, however, that it remains stationary, and the effect of the shaking is to cause fluctuations of volume in the air cavities above and below and corresponding changes of pressure at the ears of the observer.

One geophone pot is sufficient if required merely to identify a sound and gauge its distance. Two must be used when it is desired to determine the direction of the sound.



PLAN.

SECTION.

Fig. 18

LOCATING SOURCES OF NOISE

One of the most instinctive uses to which all animals put their ears is the detection and location of sources of noise. A man of normal hearing, when spoken to, is able without visual aid to gauge roughly the direction from which he has been addressed. This instinct is not possessed by those entirely deaf in one ear, and it is probably due to the fact that a sound made either to the right or the left does not reach the two ears at precisely the same time. The impressions received by the two ears also differ in loudness, but sound waves of moderate or low pitch spread readily around the head, so that the intensities at the two ears can differ by very little. The brain is able within limits to appreciate this small difference in time, and it thus estimates instinctively the direction from which the sound comes. A simple experiment illustrates this. If sound is conveyed from a point to

PLATE 18

One of the Forts at Liége after Bombardment (*Reproduced by permission of the 'Daily Mirror'*)

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the ears by two identical tubes, one going to each ear, the observer has the impression that the sound is directly in front of him, or directly behind. If the tube entering one ear is slightly lengthened, the observer feels that the source of sound has moved somewhat to the other side, the extent of the apparent movement depending on the amount by which the tube is lengthened.

If the tube is lengthened, however, by an amount comparable with a wave-length of the sound concerned, one ear receives from the source the twenty-first wave—as an example—at the same instant that the other ear receives the twentieth, and both ears get exactly the same impression; the source of sound appears directly to the front or directly to the rear. Care must be taken, therefore, in using this method for high-pitched sound which is of short wave-length. Sound ten octaves above the middle C on the piano has, for example, a wave length of only about one foot.

A trained hearer can assess the direction of sound with his ear alone within a few degrees. If a pair of large trumpet collectors is used, one connected by tubing to one ear and one to the other, the sound reaching the ear is considerably increased, and if the mouths of the trumpets are placed several feet apart, the directional accuracy is further improved.

A very important application of this principle is the use of sound locators for spotting aircraft. Large trumpet collectors are used for increasing the sound, and their mouths are placed several feet apart. The trumpets can be rotated, and the observer does this until he gains the impression that the noise 'crosses over' from one side of him to the other. At the 'cross over' the axis of the trumpets should point in the direction of the sound. Under good listening conditions an accuracy of about two degrees is attainable, but the conditions vary widely.

The illustration (Plate 11) gives a good idea of the sound locator used in the anti-aircraft divisions, and it will be seen that there are two pairs of trumpets mounted in the vertical and horizontal planes. By this means the elevation of the aeroplane above the horizon can be determined at the same time as its compass direction. Two observers are listening and finding the 'cross over' point in the horizontal plane at the required elevation. By using several sound locators at known positions well separated on the map, the actual position of the aeroplane at any given moment can be approximately inferred. It can be well appreciated that, with the speed of modern aircraft, the reporting arrangements must be well organized in order to make effective use of the information gained.

The same principle can be used under water for locating the direction of submarines, but the type of apparatus must necessarily be a good deal different. Sound travels nearly five times as fast in water as in air, and the separation of the receivers constituting the ears has to be greater than in air. Nor is it feasible to rotate the pair of receivers in searching for direction, and instead, the length of tube from one receiver relative to that from the other is increased or decreased.

Practically all underwater receivers—or hydrophones as they are called—are electrical in action. Most of them necessarily distort the sound a good deal, and for recognizing complex sounds under water rubber hydrophones are best. The technique of echo-sounding apparatus has been much developed. Extraneous noises coming from the propeller and from the engines of the vessel itself, as well as the 'water-noise' arising from the movement of water past the ship, add to the complications of a problem upon the satisfactory solution of which the freedom of the seas from the U-boat menace so much depends.

CHAPTER VIII

FORTIFICATION AND COAST DEFENCE

THE history of fortification coincides with the history of warfare itself; from earliest days man has contrived to put himself in the best possible position for fighting, at the same time endeavouring to produce unfavourable conditions for his enemy. Fortification always involves, therefore, two elements, protection and obstacle, and these two must be closely related. The former was often achieved by a wall or rampart, and it can be indirectly secured by distance—advanced forts for example—and also by concealment and camouflage.

The objects of fortification are very varied—in older days fortified cities such as Nineveh and Babylon were intended to shelter the greater part of the population; the medieval feudal lords fortified towns from which they drew their revenue. Later on the barrier forts came into being, intended to delay the march of hostile armies or to force them to attack within a relatively limited gap. Nowadays, nations with vulnerable land frontiers fortify along these frontiers so as to protect national territory from the destructive effect of modern war and from the loss of economic resources thereby entailed.

There is nowadays no hard-and-fast line dividing field works and fortification, but in general the former has reference to works constructed under war conditions, whereas fortification refers to substantial works deliberately constructed in time of peace.

The earliest type of obstacle seems to have been the thorn hedge: Alexander, that supreme captain of war, encountered many such. Then came the rampart of earth followed by the brick wall, usually double with earth filling. These walls were made zig-zag, with high towers at the angles to permit of enfilade fire along the outer line of the walls. Not infrequently a water obstacle existed outside the walls themselves. The fortifications of Nineveh, which were built around 2000 B.C., were stupendous. Its walls were 120 ft. high and 30 ft. thick, and there were 1,500 towers around its perimeter of 50 miles. It can well be imagined that attack by scaling ladders was a hopeless proposition against an active defence in this kind of work, and the besiegers often had resource to mining with a view to getting under the walls. The missile engine had not yet been developed, and it is first mentioned in the defence of Jerusalem against the Philistines in the eighth century B.C. Then followed the movable offensive tower which was adopted to enable the attackers to get on a level with the defenders; Nebuchadnezzar used these in besieging Tyre and Jerusalem in 587 B.C. The Greeks under Philip and his yet greater son Alexander, and subsequently the Greek colonists, developed the science of siegecraft, and under the Romans it became very systematic. The gunners of that era put up remarkable performances with their crude catapults and *ballistae*. These missile engines threw stones up to 600 lb., heavy darts from 6 to 12 ft. long, and they even forestalled the German *flamenwerfer* of 1915 and 1916 in throwing Greek fire. Archimedes at the siege of Syracuse devised projectiles weighing up to three-quarters of a ton whose ranges extended up to 1,000 yards.

But neither the Huns, the Goths, nor the Franks had the patience, discipline, and tradesmanship essential for siegecraft, and for many years the only method of reducing the old Roman forts was by starvation. In the eleventh century siegecraft was renewed in Western Europe, but the medieval chivalry lacked the ability of the Romans. Advantage was particularly taken of surprise, and especially on the occasion of festivals when the vigilance of the garrison was likely to be much relaxed. Step by step defences to localize successful assault were therefore a feature, and the Norman castles have almost invariably an outer series of works, an inner circle, and then a central keep which was always built over a well. Provision for counter-mining was gradually developed, but until the arrival of gunpowder the attack was in general inferior to the defence.

Gunpowder made very little difference at first, as the projectiles were very light, their aim uncertain, and the primitive guns had a playful habit of bursting and causing casualties among the defenders. In point of fact, the earliest attempts at trench mortars in the war of 1914–18 were little better. By degrees, however, the primitive cannon were improved, particularly in France, and around 1450 the French King, Charles VII, captured all the castles in Normandy held by the English, his superior ordnance being the main factor in his success. By degrees the wall was replaced by the trench for protection as gunpowder improved, and the conventional profile as shown in the diagram (Fig. 19) was evolved. The covered way was intended to allow the garrison to mass for a sortie. Ramparts for guns were constructed, and these were often mounted in 'bastions'. By degrees complicated works were constructed, sometimes culminating in fantastic designs.

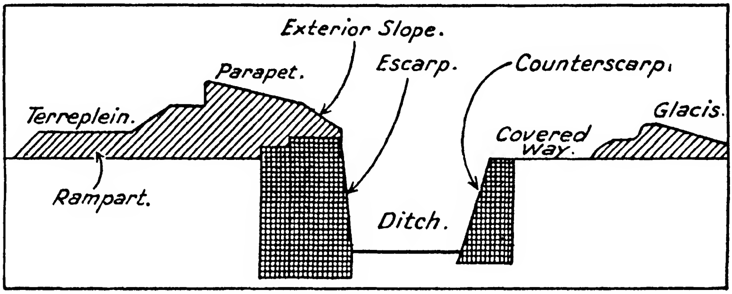

FIG. 19

Sebastien le Prestre de Vauban (1633–1707) has rightly earned the chief place among military engineers. He built fortresses for Louis the Fourteenth and did much to hold up the marches of the Duke of Marlborough. He learned his business as an offensive, not as a defensive, fighter. He only commanded at one defence—that of the siege of Oudenarde in 1674. He directed the siege of forty-eight fortresses without a single failure. Among the strongholds that the genius of Vauban created are Lille, Ypres, and Doullens. Fig. 20 is a plan of one of Vauban's best-known works, the fortress of Lille as it was in 1700. It is a good example of bastioned defence, with its ravelins and other outworks in front and its central keep; casemates and galleries for flank defence are very numerous. Very unfairly, Vauban's name is associated with many complicated and unpractical fortifications. Actually he was no believer in systems. 'One does not fortify by systems but by common sense,' he said. The French spent large sums in fortification under his guidance, but towards the end of his life he began to explain their weakness which was due to the violation of the principle of mobility. He was accordingly made a Marshal of France, which was far too dignified an office to allow of specialization in mere engineering. Soon after, both artillery and musketry were greatly improved in range and speed, and the idea of the detached fort, which had originally occurred to Vauban, was much developed. By degrees it became recognized as the correct means of protecting a city from bombardment. In 1820 the fortress of Paris was reconstructed and detached forts added at a cost of £8,000,000. The English dockyard defences, Portsmouth, Plymouth,

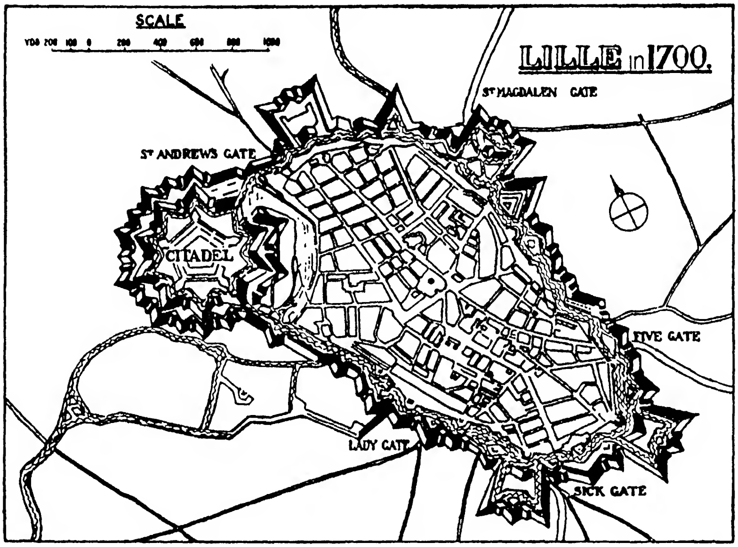

FIG. 20

and Chatham were taken in hand in the middle of the nineteenth century, and the work was then very up to date.

Some twenty years later the arrival of the rifled gun spelt the death-knell of simple masonry as a protection from artillery fire, and all existing fortresses were thereby rendered out of date. The greatest expert on fortification at that time was General Brialmont, who was responsible for the layout of the Antwerp forts as well as those of Bucharest. A good deal of controversy then existed about the position of fortress artillery, some experts considering that the guns should be located outside the forts, as indeed would have been in many ways preferable. Brialmont's solution was to put them in the forts, protected by steel turrets. In some forts the guns were sited in disappearing mountings worked by hydraulic machinery.

The arrival of the high explosive shell involved further strengthening of revetments, and it was necessary to add reinforced concrete some 6 to 10 ft. thick to existing cover.

The following points embrace the general doctrine as regards fortification at the outbreak of the war of 1914–18.

1. That important places must be defended by fortresses.
2. That their girdle of forts must be far enough out to prevent bombardment.
3. That on mobilization the forts should be connected by lines of entrenched infantry positions, with elaborate wire obstacles and deep bomb-proof shelters.
4. That some of the guns, and these protected with armour, should be in the forts.
5. That the remainder of the defensive artillery should be outside—the guns in cupolas, the howitzers in concealed positions.
6. That ample rail, road, and signal communication between the forts themselves and between the forts and the central command centre should exist.
7. That the garrison should mainly be reservist troops with a stiffening of regulars, mainly for specialist work.

The role of fortification was then much as now—its prime object is to gain time, and it is intended for three purposes :

to economize force, to free troops for active operations, and to hamper the movements of the enemy. As regards expense, in comparison with the cost of modern frontier fortification of the Maginot line type, that of the pre-1914 works was surprisingly small. The total expenditure by France on the defence of Verdun and the heights of the Meuse between 1874 and 1914 was well within eight million pounds. Not a great expenditure for the blocking of the direct line of advance into France.

In 1914 the great barrier forts along either side of the Franco-German frontier were not attacked in the first instance, though they exercised a profound influence on the strategic developments, as the Germans would hardly have attacked through Belgium had they considered direct attack on France likely to be successful. One of the initial surprises of that war was the speed with which the fortresses attacked by the Germans fell. The three Belgian fortresses, Liége, Namur, and Antwerp, were thought to be thoroughly up to date, but there can be little doubt that the work had been defectively carried out, and that arrangements for ventilation and for ammunition storage were unsuitable; moreover, the forts had not been designed to withstand the heavy projectiles used by the Germans.

Liége was defended by 12 forts arranged over a 30-mile perimeter—its garrison amounted to 20,000 troops, in addition to the artillery and engineer personnel of the forts themselves. After unsuccessfully attempting to storm the gaps between the forts on 5th August, several brigades were successful in penetrating to the heart of the city next day. The forts held out, however, the last not surrendering until the morning of the 16th—the state of one of the forts after its bombardment is shown in Plate 18, reproduced by permission of the *Daily Mirror*. The Germans employed howitzers of calibre up to 17 in. against the forts.

Namur was even more important to the Allies than Liége, though less imposing, its nine forts being on a perimeter of 25 miles. Its garrison was about the same as that of Liége. Here the Germans attempted no attack until their heavy howitzers were in position. The first shot was fired on 20th

August and by 25th August the last of the forts had been destroyed.

The circuit of the Antwerp forts was over 60 miles, and the force available for its defence was about 100,000 men. On 28th September the Germans opened fire with their siege trains, and by 1st October the four forts on the south-east of the city were out of action. For the next few days the Belgian troops, reinforced by some 8,000 men of hastily collected units of a British naval division, held the line of the rivers Nethe and Rupel, some ten miles behind the line of forts. When the Germans penetrated this line the defenders fell back on the inner circle of forts, which was the main line of defence of Antwerp a century ago. This line could not have protected the city from the north, and ultimately the greater part of the garrison retreated to the west, this part of the city not having been invested. The city was surrendered on 9th October.

The only French fortress that was besieged in 1914 was Maubeuge, through which city the British retreated after the battle of Mons. The fortifications were obsolete, some having been constructed in 1888 and others in 1899, and they crumbled rapidly when the German heavy siege train, including 42-centimetre howitzers, arrived. The fortress commander had a garrison of about 40,000 men, mainly composed of second-line troops, ill suited for active operations. He put up a vigorous defence with the limited resources at his command. The town was isolated by 25th August, and three days later the bombardment began. In spite of some active sorties, the defenders had been pressed back almost to the walls of the town by 7th September, and the Germans occupied the town on 8th September. In spite of the rapid success of the Germans against Maubeuge and the Belgian fortresses, there can be no doubt that their defence enabled necessary time to be gained. Liége and Namur enabled the less rapidly mobilized French Army to face up to the Germans without serious lack of preparation, and Antwerp and Maubeuge held up some four army corps of the German Army till after the battle of the Marne, and in addition the vital railways passing through Maubeuge could not be used by the invaders for this all-important battle. Von Kluck's supply arrangements were much hampered by this.

The French read the wrong lesson from the fate of Liége, Namur, and Antwerp. It was incorrectly assumed that the pre-war forts were useless and they were dismantled, and when the Germans captured Fort Douaumont in the Verdun defences it was garrisoned by a handful of Algerian soldiers. Later on it was realized that such forts as Douaumont and Vaux were of much value owing to their shell-proof nature and their commanding positions, situated as they were as strong posts in the defended zone. During the war Douaumont alone received direct hits from a million shells, and only one penetrated into the shell-proof shelters, and this one was fired by the French during the German occupation of the fortress and from the direction of Verdun itself. Certainly the French reconstruction of Verdun was vastly superior to the work carried out by the Belgians on their fortresses.

What then are the modern developments as regards fortification? The progress of mechanization causes the military machine to depend more and more on science and industry. It is becoming more complicated, more costly, and less robust. The attacker seeks success by sudden and rapid attack, and in this, armoured fighting vehicles, and above all aircraft, exercise a preponderant influence. With the invasion of national territory economic resources become reduced, and no country can afford the loss of ground such as the French sustained in 1914. Fortifications of nations with vulnerable land frontiers run close to the frontier itself, and extend over an area of up to 20 miles in depth. No longer can reliance be placed on a single girdle of forts sited at points of great tactical importance. In the siege of Port Arthur in 1904, for example, the fate of the fortress rested on the capture of any one single fort in the line of heights on which the permanent forts had been placed. These forts were very conspicuous and were constructed of concrete with deep ditches all round. They contained siege guns as well as infantry, and the infantry suffered from their ill-advised proximity to the guns. Once the Japanese had occupied *203-metre hill* they had the Russian navy, dockyard, and the fortress itself at their mercy.

The type of work in a modern fortified area depends essentially on the topographical features—in hilly country Nature herself provides many of the defences, as also on low-lying ground where inundations can be rapidly effected. In general the foremost works consist of a series of reinforced-concrete 'pill-boxes'. In the positions in front of Metz, built by the Germans during the war of 1914–18, there were no fewer than 800 such on a front of less than 2 miles.

André Maginot, a man of heroic dimensions, 6 ft. 2 in. tall and a tremendous eater, particularly of oysters, was Minister of War in 1929 when the Maginot line was begun. The pill-boxes of the Maginot line cover a comprehensive system of tank stops. These consist of steel rails driven into the ground with the points upward, and they are planted at different heights so as to 'belly' any type of tank. The French Tommies call them 'asparagus', and in the second line they become 'lethal asparagus' with an explosive charge on each rail for the further delectation of any tank attempting to break through. Behind is a series of mutually supporting works, becoming ever more formidable as the position is penetrated. Guns are mounted so that they can be fired with the crews completely protected, the gunners laying the guns by following the indications of a dial controlled by an officer in a separate armoured chamber. Underground barracks exist wherein troops may live in complete safety in the heaviest bombardment, and in these chambers a slight positive air-pressure exists, so that there is no tendency for gases from outside to enter, filtered air being pumped in. Heavier guns in camouflaged positions exist in rear, and well-protected underground hangars for the defence aircraft are also provided. Between 1929 and 1935 more than sixty million pounds were poured into the building of the Maginot line, and since then many more millions have been spent. Moreover work on the Maginot line never stops. Every new month fresh developments are incorporated into the fortifications and new ideas are woven into the fabric of the defence. One of the characteristic features of a defensive zone of the Maginot line type is the inconspicuous nature of the fortifications from the ground or air.

André Maginot, who conceived it all, died in January 1932 from typhoid fever contracted from eating his favourite oysters. He was only 54, but he will go down to history as the supreme defender of his native Loraine and of France. 'La Ligne Maginot' guarantees the liberty and security of the whole democratic world.

The lesson of the last war as regards personnel has been taken to heart, and no longer is second-line personnel considered adequate for fortress work. In the French Army, highly trained troops in special regiments with large peace establishments are permanently allotted to the Maginot line, and special precautions are taken to combat the disabilities that troops are liable to suffer from living underground in time of peace. Hot water is laid on in the barrack rooms and electric cooking is provided. There are subterranean canteens, hospitals, and telephone systems, vast mess-rooms, dormitories, and power plants. Some of the great forts, like the Haguenan and the Hochwald, have every calibre of artillery from the giants which hurl shells over 20 miles, to the new 33-millimetre gun, which has proved of tremendous utility as an intermediate weapon between the famous 75-millimetre and the heavier machine guns (Plates 1, 19, and 21).

The garrison regiments are known in the French Army as *écrevisses de rampart*, and in peace the normal routine of these 'shell-fish of the fort' is 15 days in the line, 15 days at rest, and leave allowance is unusually liberal. Rates of pay are higher than for the field army, and as one officer and one N.C.O. is required for every 12 men, promotion is rapid in these units. Ammunition is stored 150 ft. below ground and is brought to the gunners by electric lifts. In the unlikely contingency of casemates being forced there are impervious partitions to localize enemy success, not unlike the watertight partitions of a battleship. The analogy of a fleet at anchor does indeed give the best description of the Maginot line, with the light scouting craft analogous to the pill-boxes well forward, the cruisers occupying the medium position and corresponding to the medium artillery, and the capital ships corresponding to the underground forts with their heavy guns and howitzers in the rear. There is, however, no sealed pattern type of work and infinite variation conforming to the terrain itself is arranged. A complete system of anti-aircraft guns and searchlights is in being, and further very comprehensive obstacles are continually being added. Nothing that modern ingenuity and military science can achieve has been neglected in the construction of the Maginot line, on which the security of France from invasion so much depends; and, as armies are at present constituted, the line garrisoned by skilful troops in adequate numbers can be considered as impregnable.

But what of the future? Military science is always advancing, and it is unlikely that this invulnerability will be permanently maintained. Consider one contingency alone—the dropping by parachute of considerable formations in rear of the defended zone. The Russians have been attempting this with some success on manœuvres with a whole brigade and it was done by the Germans on a relatively small scale in their Polish campaign, and although such matters as supply and maintenance are likely to constitute formidable problems, the possibilities of this type of offensive are almost unlimited. It cannot, however, be too much emphasized that deliberately prepared defences under modern conditions lock up large numbers of trained personnel, and thereby may prejudice the operations of field armies.

The Siegfried line, though bearing many resemblances to its French opposite number, has also many differences. As pointed out in a series of articles by Captain Wynn in the *Army Quarterly*, the key to the Siegfried line, or Siegfried position as it is much more accurately termed, is to be found in its namesake, evolved by Col. von Lossberg under Ludendorff's guidance over 20 years before. Since then weapons have changed and the depth of the defensive zone has much increased, extending up to at least 20 miles in places, but the rigid lines were then as now replaced by successive zones of defence, with an outpost area of considerable breadth for delaying action, ever stronger resistance as the position is penetrated, with a wilderness of machine-gun nests and strong-points, and finally mobile divisions, motorized and mechanized, kept out of the effective range of all but the heaviest artillery. In the Siegfried *Stellung* there may be less steel and more concrete than across the frontier (see Plate 20), but of the formidable nature of the works there can be no doubt.

One of the first requisites of every fortification is that it should help to economize the defender's man-power in order to enable him to utilize it at the decisive point. Anyone seeing the vast girdle of defensive works—many of them only partly completed—erected by the Czechoslovaks, could hardly fail to question what would have been left to form a field army after adequate garrisons had been allotted.

THE COAST DEFENCE PROBLEM

As the greatest naval power with world-wide defensive responsibilities, coast defence is a matter of supreme importance for the British Empire, and it concerns the Navy quite as much as the Army.

The first occasion upon which large sums were spent on coast defence in Britain was in the Napoleonic wars, when numbers of Martello towers were erected on the coast in threatened areas. The Hythe military canal—mainly intended as a water-gap—was also dug. In the war of 1914–18 mutually supported pill-boxes were erected along the east coast, and also on roads leading inland. A good deal of barbed wire fence was constructed on the beach and buried telephone cable was dug in on the cliffs. Some home-service divisions were employed on coast defence duties, and mobile yeomanry cyclist brigades were available a few miles inland. When the man-power situation became serious the home-service divisions were replaced by battalions of young soldiers in training for service overseas.

The principles underlying coast defence are similar in essentials to those of any other type of military activity, and final success cannot be attained by passive defence alone.

In our coast defence commitments it is assumed that naval power superior to the enemy will be available in due course, but important naval bases and dockyards will require defence from air attack as well as from naval attack until such time as a concentration of superior naval forces can be secured. The security of large commercial ports handling supplies from overseas is also a matter of considerable importance.

In the last war there was only one case of an attack by German ships on a defended British port. This was on 16th December 1914, when three German cruisers engaged the defences of West Hartlepool at 2½ miles' range, having approached under cover of mist. The shore battery consisted of three 6-inch guns, but the ships were too heavily armoured for any vital part to be damaged by these. In the shore batteries there were no casualties, but in various defence posts outside the batteries there were twenty-eight casualties in killed and wounded. The range-finding station close to the batteries was so badly shaken by the concussion of enemy shells as to be of little use, but the guns, ranged by their automatic sights, inflicted damage to the upper works of the ships and casualties on the crews, and the vessels withdrew after less than three-quarters of an hour in action.

In the evolution of modern coast defence the main factor has been the armament of the attacking ship, as the further contingency of air attack has only recently arisen. In this connexion it must be remembered that ships are designed to fight ships and not land fortifications, and they suffer from serious handicap in a contest with forts on land. At the time of Nelson a three-decker had 66 guns on each broadside and could fire 330 rounds of an aggregate weight of some 6 tons in 5 minutes, and in weight of metal and rapidity of fire she could outmatch the shore battery of the day, which fired from open emplacements, thereby crushing it by sheer superiority of metal and rate of fire. This was even more the case when round-shot was superseded by shell, and the land battery of stone with casemates, and guns firing through embrasures, became a necessity. In order to compete with the ships, forts were built with two or three tiers of guns, and this resulted in overcrowding of the armament.

The introduction of rifled artillery, with its increased penetrative power, led to the introduction of armour for the protection of ships, and to iron shields for the front of the gun casemates of forts. A further development was the complete iron fort armoured all round, closely approximating to a stationary battleship; examples of this type are to be seen at Spithead, Plymouth, and Portland. It soon became evident, however, that the progress that was being made in the range and power of artillery was rendering such forts quickly out of date and turning them into veritable shell traps. As a result of this the casemated fort gave way to guns firing from open batteries. At first the desire for adequate protection led to the device of disappearing mountings, enabling all the operations of loading to be carried out below the level of the parapet and under cover of a horizontal steel shield. Hydro-pneumatic mechanism had to be provided for this, which was an added complication, and it was impossible to achieve a high rate of fire with this type of mounting. An attacking squadron of ships is a fleeting target, and it is essential that the guns of a shore battery should have a high rate of fire; and it is only the open emplacement that can secure this and obtain the advantages of a wide arc of fire, which ensures the fullest development of the power of the defenders' weapons. Rapidity and accuracy of fire have been increased also since the invention of automatic sights, and especially at the shorter ranges. Protection of the gun's crew is achieved by steel shields, which are splinter-proof, but no immunity is provided against a direct hit. The vertical area of target offered by a 9·2-in. gun, end on, is only about 50 sq. ft., and by careful concealment and dispersion the chances of a direct hit are much reduced.

There can be no doubt at all that shore batteries have certain marked advantages in their combat with ships, and an attack on shore batteries is a duty which is most unwelcome to a naval commander. Naval guns fire from an unstable platform and cannot hope to attain the accuracy of which shore guns are capable. Furthermore, the vulnerable area of a land gun is very small in comparison with the target offered by a battleship. Such a ship offers to the land gun a target about 30 ft. high and up to 400 ft. when broadside on, and, somewhat unexpectedly, an even more favourable target is offered when end-on, owing to the fact that the inherent errors of the gun are greater as regards range than as regards direction. Some of this target is usually armoured, but much of it is vulnerable. Nor can a ship hide itself in a way that is feasible for a well-sited land battery.

Efficiency in range-finding is principally a matter of getting as long a base as possible, and a battery is better off in this respect than a ship. Moreover, the fall of a shell is far more easily observed on sea than on land. Ships' guns, as already mentioned, are intended to engage other ships, and the shells are necessarily of high velocity and flat trajectory, with their oval stream-lined shells and delayed-action fuse, which is less suited for damaging land batteries than is high-explosive shell and quicker acting fuses. Nor can a ship have as much ammunition available owing to lack of space and lack of facilities for early replacement.

History does not provide a single example, since the bombardment of Alexandria in 1882, of a fleet being overwhelmingly successful in action against shore works. In the Dardanelles, although the Turkish works were antiquated, faulty in conception and design, and very conspicuous, the naval bombardment caused the permanent disablement of very few guns, and landing parties effected the demolition of the guns of the outer defence group. In the attempt to destroy the inner defences, the ships were compelled to be continually on the move, owing to the fire of well-concealed and dispersed howitzers. After the destruction of three of the Allied ships by floating mines, the naval action was abandoned, hardly any permanent damage being done to the defences.

The German defences of the Belgian coast were built up from an entirely unfortified and not very suitable terrain, in spite of repeated bombardment by British warships. The primary armament came to include 15-in. guns and 11-in. howitzers sited behind the belt of sandhills, in low-lying emplacements entirely invisible from the sea. There was also a large number of smaller guns in the secondary armament, mostly sited for direct fire and making provision for close defence. Finally, there was a complete system of defence against landing. Use was made of railway mountings for some of the heavier guns, and many of the guns of the secondary armament were cleverly disguised as parts of farm-houses or other civilian objects. Searchlights were arranged to illuminate the whole front, and beyond the range of illumination a star shell barrage was used. Anti-aircraft defence included aircraft, guns, machine guns, searchlights, sound locators, and kites. Some of the guns fired alternate rounds of high explosive and green tracer shells, which the R.A.F. knew as 'flaming onions'.

Both the attack and defence of coast fortresses must usually be regarded as an operation in which navy, army, and air-force are all implicated. To gain possession of a properly defended post, by naval and air attack unaccompanied by land attack, cannot be normally regarded as a practicable proposition.

Before the war of 1914–18 the largest British coast defence gun was the 9·2-in. gun, for the not very adequate reason that this was the largest piece of ordnance for which, in an emergency, hand loading is practicable. Owing to the advantages already enumerated, coupled with the expected supremacy of the British Navy on sea, such defence was considered adequate. But in the later years of that war 12-in. guns on naval turret mountings were used, operated by electric and hydraulic power. Each unit was self-contained, having magazines and engine-room, well protected and below the gun platform, the ammunition being delivered by power-driven hoists on naval lines. This feature persists in even larger units in the reorganized defence of our naval bases and overseas defended ports, the heavy guns in their armoured turrets being frequently in pairs as in a warship. Camouflage is usually arranged so as to distort the form of the turret, as it can rarely be adequately concealed from air observation.

In a first-rate fortress the armament is divided into three main categories:

1. Anti-ship armament.
2. Anti-aircraft armament.
3. Movable armament.

Anti-ship armament includes counter-bombardment guns, both heavy (above 9·2 in.) and medium (9·2 in.), primarily intended to engage, at long range, ships attempting to bombard the fortress (Plate 22). Medium guns may also be used against block-ships and boom-smashers, for which defence searchlights are probably necessary. The fixed heavy artillery is often reinforced by railway artillery with 8-in. and even 10-in. guns, the bogie platform being secured to the rails by special grappling tackle. The Germans make no secret that they have designed some monster railway guns of this type. The Americans have even produced a 14-in. gun mounted on rails.

Close defence guns—mainly 6 in. and 4·7 in.—are provided to engage vessels attacking at short range or for the defence of beaches. Close defence guns are always provided with searchlights. Howitzers and mortars are often mounted in sunken concrete emplacements.

The third category of anti-ship armament is the 12-pounder or 6-pounder gun, intended to engage motor torpedo-boats or other light vessels endeavouring to enter the harbour for torpedo attack. Such craft are now in existence with speeds up to 52 knots. Defence searchlights include concentrated movable beams to detect the appearance of hostile craft, fighting lights to illuminate targets engaged by the close defence guns, and dispersed beams providing an illuminated area covered by the light anti-motor-torpedo-boat armament. Owing to absence of restrictions affecting weight and space, land searchlights are much superior to those on board ship. The largest lights have a beam whose length is many miles. For yet greater height, medium artillery star shells may be used, as also when it is desired not to let the enemy know the position of the lights. A modern development, already mentioned, is the use of infra-red rays in conjunction with listening instruments. It may be possible by this means to fix the position of an aeroplane before the attack with such accuracy that the use of searchlights may be avoided altogether.

The anti-aircraft armament consists of guns specially designed for engaging aircraft and sited for general anti-aircraft defence of the fortress, in co-operation with the necessary anti-aircraft searchlights. Also light automatic weapons, machine guns, or specially designed scatter guns, intended for use against low-flying attack somewhat on the lines of the naval multiple pom-poms, are available. Anti-aircraft artillery has improved beyond all expectation in the last few years. Calibres range up to 5 in., and there is little doubt that further increases will follow. The American 5-in. anti-aircraft gun fires up to 39,000 ft. Guns up to 3 in. are mostly fully automatic, with a rate of fire of 25 to 30 rounds per minute.

The movable armament consists of medium and field artillery equipment, intended to assist the defence by action against land fronts and against attempted or forced landings.

Besides the various categories of artillery, there are also other passive defence appliances that are of the greatest importance. Sound-ranging, for example, is of considerable value in locating sea targets.

Boom and other floating or fixed obstructions perform for harbour defence the same functions that wire entanglements perform for land defence, and they must be sited with reference to the defending artillery.

Submarine mines combine the functions of a weapon with that of an obstacle. Their moral and material influence on naval attack is considerable, and they can only be cleared by the slow process of sweeping with small vessels. Charges now run up to 660 lb. of T.N.T., and mine-fields intended for the defence of coast and river-mouth are normally laid in the 'war imminent' stage, commercial ships being conducted through the fields by pilots. Two varieties of mines are in use:

(a) Controlled mines which are laid in lines on the bottom of the fairway and are connected by cable to the mine-field control station ashore. Duties in connexion with these mines used to be carried out by the Royal Engineers, but have now for many years been carried out by the Royal Navy.

(b) Contact mines which are attached by a mooring line to a sinker. The mine is kept at a constant depth through the action of a hydrostatic balance and explodes when hit. Developments since the war of 1914–18 include the so-called 'antenna' mine. On the upper part of the mine is an 'antenna' kept in an upright position by means of a float. When a ship comes into contact with the 'antenna', a circuit is closed and the fuse mechanism is set in motion. In one species of mine, when the ship fouls the 'antenna' the occurrence is registered either optically or acoustically in an observation post on land, where the mine can be exploded by remote control. Contact mines are a two-edged weapon, but are of service in denying the use of sea areas which might be of value to the enemy.

The preparation and defence of naval fortresses has very much preoccupied the British defence services in the last few years. Over twenty million pounds has been spent on Singapore alone, and this naval base, with its many natural advantages, has become a pivotal point in the defence plans of the British Empire and allied countries in the Far East. It now incorporates a giant graving dock that can take the world's largest battleship, and all the features necessary for the defence of a first-class fortress have been incorporated. Its weakest feature was the smallness of the military garrison, but this has been remedied by large reinforcements from India. It is the western point of the Far East defence triangle, north-north-east of it being Hong Kong, south-east of it Port Darwin, which the Australian government has fortified. Hong Kong, which is a crown colony with a population of one million, was originally an island of 32 square miles. It has now an area ten times as great owing to the cession of the peninsular of Kowloon in 1898. This adds considerably to the defence problem with a land frontier of some 20 miles to defend. Luckily the terrain is hilly and there are suitable defensive facilities, with large tunnels in the granite for air raid protection. Hong Kong has not the vast defensive strength of Singapore, but it can be depended upon to hold out for many months, during which period it is to be expected that naval assistance will be forthcoming. A good deal of fortification work is also in progress in minor naval bases on the African continent—Simonstown, Freetown, and Alexandria are all capable of sheltering British merchant ships as well as satisfying naval requirements.

In all defended ports the defence scheme provides for a precautionary period and a war period. In the latter period a considerable amount of digging, wiring, clearing fields of fire, and the like is carried out, which would not be feasible in time of peace. Quick-setting concrete lends itself for purposes that secure an enormous strengthening of defensive possibilities, and it is now feasible even more than in the last war to build up defences in districts that at first sight would appear by no means suitable. What is essential is that the necessary warlike stores—guns, lights, engines, wire, cable, mines, and a hundred and one ancillary requirements should be available, and the rearmament programme enabled these to be widely supplied even before the outbreak of war in September 1939.

CHAPTER IX

CHEMICAL WARFARE

CHEMICAL warfare, as conceived nowadays, dates from 22nd April 1915, when the Germans surprised the world by discharging chlorine gas from cylinders let into their trenches near Ypres. Casualties amounting to 5,000 dead and 10,000 wounded were sustained—mainly by the French Algerian troops and the Canadians. Both guns and ground were lost, but the German Higher Command, who distrusted the innovation, failed to exploit the advantage, as they had no conception that the initial attack would be so successful. In 1889 the German Government, in conjunction with practically all other nations, had signed the Hague Convention prohibiting the use of gas in war, but the surprise need not have been so complete if intelligence reports had not been so flagrantly disregarded. Cloud-gas attacks against the Russians had even been tried in the first week of February 1915, and gas cylinders had been found in dozens near Zillebeke at the end of March 1915, but no notice was taken of the reports.

Readers of Martha McKenna's intriguing book *I was a Spy* will remember that she herself reported the arrival of jealously guarded and very mysterious gas cylinders behind the German lines, and that she was told to confine herself to military intelligence as 'the British Army was not concerned with the trading affairs of the German nation'. It is only fair to add that the French Intelligence Service was even more to blame in this respect.

Armies have now a chemical intelligence service which includes trained chemists, since the ordinary military staff officer has not the requisite scientific and technical knowledge. A few days before the first German gas attack, several German wireless messages were intercepted which indicated anxiety owing to the unfavourable direction of the wind, and reference was also made to one 'Haber'. A trained chemist would have known that Haber was one of the leading chemists in Germany.

In their initial cloud-gas attacks the German Command can hardly have taken into account the fact that the prevailing wind in Flanders is south-westerly, and this factor was very much in the Allies' favour. Actually, after this initial success the wind was unfavourable to the Germans for some weeks.

The subsequent history of the gas campaign is a series of attempts by each side to produce a new gas which would penetrate the enemy respirator, and a series of efforts to secure superior methods of gas projection. The gases employed gradually became more deadly. Chlorine, for example, is only lethal if employed in concentrations of one part in 2,000 for two minutes. Its main claim as a war gas is that it can be so easily made and that large quantities are available. Phosgene, which was tried next, requires only one-fifth of this concentration for lethal effect. One of the toxic smokes, on the other hand, like chlorarsine (called DM) will produce the most unpleasant symptoms and stop troops from active fighting if supplied in concentrations of one part in 10 million. Even one twentieth of this minute concentration (i.e. one part in 200 million) if breathed by a man for five minutes will bring about the same effect as is achieved by a small boy who smokes a strong cigar, or by a bad dose of influenza.

Chlorine mixed with smoke was used by the British in September 1915 at Loos, being projected both from cylinders and from mortars. It secured some tactical success, as the Germans were very imperfectly protected by gauze and cotton pad respirators, but the wind was not very suitable and many mistakes were made.

About this time German prisoners were captured who boasted of a new German gas. Our scientists suspected phosgene, which would necessitate a new reagent in the respirators for the protection of our troops. The early respirators used 'hypo', but to protect against phosgene 'phenate' was added. Luckily this was introduced in time to negative the effects of the German phosgene attacks of 19th December 1915.

Phosgene ($COCl_2$), used in dyeing, an industry very much in German hands in the years previous to 1914, is a heavy gas which can be easily and cheaply manufactured. Its action is to produce much watery fluid in the lungs, and the severely gassed man dies as from drowning, i.e. flooding of the lungs. It causes less coughing than chlorine, which coughing restricts the intake of the poison. At first it was thought that phosgene—a compound of carbon monoxide and chlorine—had properties very similar to those of its two constituent gases, but it was subsequently found that it had a subtle physiological effect all its own. A soldier who had breathed in a relatively small intake of phosgene, and who had felt no symptoms at all, would suddenly collapse and die 24 hours or even 48 hours afterwards. The effect of this on the morale of the troops can be well imagined.

Phosgene, mixed or unmixed with other gases, became our main battle gas in the last war. It cannot be used by itself in cylinders; its liquid boils at 46° F., so that in winter time, and often at night in summer months, its vapour pressure is insufficient to force it out without help and some propelling agent is required, as in a soda-water siphon. It is desirable that the propelling gas should itself be toxic. Chlorine suggested itself, and a mixture, half chlorine half phosgene, was employed. This was called 'White Star' gas, from the sign on the cylinders which contained it.

Some of the other gases used by the British during the last war were as follows:

Chloropicrin, which came into use a good deal in 1917 and which has a number of desirable offensive properties. It is a lethal compound causing inflammation in the lungs with a degree of toxicity between phosgene and chlorine. It is a strong lachrymator, and could penetrate the German masks that were first used in 1917. The irritation in the eyes, together with the coughing and the vomiting, tends to cause the victim to remove his mask, and for this reason phosgene was often used with it.

Green Star Gas, which was used towards the end of the last war, consisted of chloropicrin 65 per cent. and sulphuretted hydrogen (H_2S) 35 per cent. It was under high pressure, and for that reason it was undesirable for it to be taken into trenches owing to risk of leakage. It was not inflammable in spite of its H_2S content.

Diphenyl Chlorarsine, called by the British DA, was one of the gases only used towards the end of the campaign. It causes tears, sneezing, and irritation to the breathing organs, but it has no blistering effect. One part in a million produces intolerable irritation but no serious after-effect. When scattered by high explosive it was liberated, not in the form of a gas, but in fine particles like the smoke of a cigarette. This type of gas is called a toxic smoke.

The manufacture of DA is an extremely complicated and laborious process, and a slightly different, but equally effective, compound known as DM was discovered. DM (called by the Americans 'Adamsite') has longer lasting and more penetrating qualities than DA.

In order to prevent a smoke from penetrating a respirator, it is necessary to add a filter, and cheese-cloth was used for this. By an accident it was discovered that a toxic smoke is more penetrating if actually gasified by heating. Here again the effects are temporarily worse when the respirator is first put on, thus making the soldier think that his respirator is useless. Mental distress follows bad cases, requiring forcible restraint to prevent suicide. However, it is impossible to get lethal concentrations, but this can be supplied when the victim is constrained to take off his mask. As it contains arsenic, DM will poison food.

It was the intention of the British to use vast supplies of DM against the Germans and much success was expected, as their gas mask did not lend itself to the necessary modification. The Armistice saved them from this infliction.

Of the tear gases there are two main varieties. The non-persistent type, called CAP after its lengthy chemical name, is effective in one part in 5 million. In the field a larger concentration is not feasible. It is much used for police purposes in the United States, the solid being dissolved in liquid and squirted out.

Persistent tear gas is called KSK, from South Kensington where experiments on it were made. It smells of peardrops, the blinding effect usually coming before the smell; it is difficult and expensive to manufacture. The liquid falling on food will poison it.

Of the many horrors of war that come through the air an interesting one is BBC. It has a persistent, very penetrating smell. Under suitable weather conditions the lachrymatory effect may be noticed several days after contamination. It is perhaps only fair to add that the BBC referred to in this case is bromo-benzyl-cyanide.

The tear gases have no other than very temporary effect, for which reason their use by themselves in warfare is not very practical.

The Germans achieved two gas successes in the 1914–18 war, firstly in its initial use and secondly in the use of mustard.

Mustard (dichlorethyl-sulphide), called by the Germans Yellow Cross, was first used on 12th July 1917, and although a day or two later it was identified, the delay involved in getting a new gas into production is such that very little mustard was used by the Allies in the remaining sixteen months of war, during which time the British casualties from mustard alone ran into six figures. Actually, supplies of mustard gas shells were available by September 1918—the French were rather quicker and they used their 'Yperite' shells, as they called them, in June 1918. In the same way it took eight months after the decision to use chloropicrin before it could be used in the field.

Hitherto with all gases it had been merely a question of getting the troops well trained in using a gas-mask. Henceforth the gas mask at the best only protected the eyes, the face, and the breathing organs. The liquid, and to a lesser degree the vapour that emanates from the liquid, causes a poisonous wound to any part of the body with which it comes into contact. Mustard is not a gas at all, but, as used in its crude form, is a dark brown oily fluid. In its pure form it is straw-coloured, and it then has very little smell. It was an irony that it was discovered in 1867 by an English chemist, but until the war of 1914–18 it was merely regarded as a very noxious and entirely useless substance. Crude mustard boils at 430° F. and freezes at 41° F. When around about its freezing-point it is entirely ineffective, but as the temperature rises above this point it tends more and more to give off its poisonous vapour. The boiling-point of water is 212° F., and it will be seen that the evaporation of mustard is far slower and therefore takes place for a far longer time than water, and this property is known as *persistency*. A spot of liquid mustard, a pin's head in diameter, will produce a poisonous ulcer about the diameter of a shilling, and this may take several months to heal. It is, however, purely a local poison.

Mustard has an affinity for fats and oils, and it gets through the skin and dissolves in the layers of fat under the skin. It was so called by the troops from the supposed resemblance of its smell to mustard. Actually its odour is more nearly akin to that of garlic. Mustard gas has great penetrating power. It eventually finds its way through most materials except those with glazed surfaces such as metals, glass, or tiles. It penetrates ordinary clothing in about ten minutes. It is readily absorbed by wood and leather. Water has very little effect on mustard; anything that contains chlorine or other oxidizing agents will destroy it, hence the use of bleaching powder, which is very effective. In fact, the effect of bleaching powder on undiluted mustard is so powerful that it bursts into flame, producing a very lethal smoke.

It can be appreciated that it is a tremendous casualty producer, but it is not particularly lethal. Only 2½ per cent. of our mustard casualties died, and these mainly from other causes. The vapour is not, of course, so poisonous as the liquid, but a concentration of one part in a million for an hour poisons the skin and will cause temporary blindness if the eyes are affected. A spot of the liquid causes permanent blindness, and for this reason goggles are worn by troops if there is the slightest likelihood of the presence of mustard spray in the air. The gas-mask gives full protection for the lungs, but owing to its insidious nature, troops often breathed mustard vapour without masks and actually the lung cases were by far the worst during the war. This would occur, for example, if troops working at night should, unbeknown to them, get mustard on their boots and equipment. If a soldier so contaminated should go into a warm dug-out, the resulting vapour would cause all the inmates to become casualties if the misfortune were not discovered.

The only other blister gas likely to be used is lewisite, which was an American discovery, but which was not produced in time to be used by them in the war. Lewisite is rather more poisonous but less persistent than mustard and it is not so subtle, as the smell (of geraniums) is intolerable. Furthermore, it is destroyed by water. As it contains arsenic, the blisters should be pricked after formation.

The enemy may use gas to inflict casualties, to harass, or as a means of delay, and blister gas is useful for all three purposes. It can be applied in a variety of ways, but its effectiveness depends on the state of the weather, on the state of the ground, and on the topographical features. All officers should know something about this and about the means of effecting decontamination. It is worth noting that aircraft spray can be used in any weather in which it is possible for aircraft to fly.

Of the various methods of projecting gases, the earliest method, by means of cylinders fixed on to the parapet of trenches, is only possible in the case of the gases of the non-persistent type like chlorine. Moreover, it is only possible in static warfare and exposes the men in the trench to certain risks. In mobile warfare, what is called the 'beam' method can be employed, and in this the cylinders are placed in lorries or railway trucks and are opened electrically, the gas travelling with the wind in a cone-shaped cloud. Such attacks have been effective at a range of over 7 miles.

In the case of *generators* the gas is discharged in an arrangement similar to that used by the troops in producing smoke. This is the best way to put over toxic smokes and can be very effective if wind and weather suit.

A method favoured by the Germans in the 1914–18 war was to fire gas-shells, but the gas content of the shell is small for its weight and some of this is lost in the shell crater.

Mortars can be used for this same purpose, but the British found that the Livens projector-drums gave the best results. These are metal drums containing a large quantity of gas and discharged from rough metal tubes by charge-boxes fired electrically and exploded by a burster and time-fuse. The range of the projectors is about a mile. The drums used weigh about 60 lb., having a gas content of about 35 lb. A strong concentration of gas on the target can be produced with a high degree of surprise, especially at night, and the arrangement is cheap and easy to produce. A good deal of labour is required in preparation and the projection is not very accurate. In Flanders on one occasion 6,000 projector bombs were fired by the British at once, and at times hardly a night passed without a projector discharge at some point in the line.

Another direct method of contaminating by blister gas is by means of the hand-contamination bomb. This weighs 6½ lb., and contains about 4 lb. of mustard gas. It is fired by a time-fuse or electrically, and is useful for the contamination of cross-roads, or of a defile in a rear-guard action. The mustard is sealed inside the bomb and is therefore safe to handle.

A simple means by which troops can produce a strong contamination is to fill an oil-drum with mustard and to burst it by means of a small charge of explosive on the approach of the enemy. But the most effective method of projecting blister gas is from aircraft, and this may be done by bomb or by spray. In the case of bombs a much higher percentage gas content is possible than in the case of a gas shell, as the bomb itself does not have to be thick enough to resist percussion in the barrel of the gun.

Medium and small bombs spread contamination most. A 50-lb. streamlined bomb contains 35 lb. of liquid mustard gas; the same amount of gas is contained in an 8-in. shell weighing 250 lb. Glass bombs (beer-bottles) or petrol tins filled with mustard can be used, no burster charge being required. A beer-bottle should not be filled more than about three-quarters full, or it may not break when it reaches the ground.

Gas can be sprayed rapidly from aircraft over extensive areas, and this method would mainly be used against personnel. It is for this reason that troops carry gas-capes. Much of the success of the Italians against the Abyssinians was due to spray, but they were dealing with an enemy who had little clothing and no protective devices.

The advantage of spray is that it is both silent and invisible, and is likely to come as a complete surprise. It can be distributed over a much greater area than the same quantity of gas discharged from bombs, but for the same reason the contamination is much less gross. Both trees and houses give complete protection, and so do bivouacs made of protective capes. Tents give partial protection, the amount depending on the degree of contamination.

The equipment supplied to the troops for protection against gas is divided into two classes:

1. The personal protective equipment which is carried by the man, and this consists of the service respirator, anti-gas goggles, a protective cape, and protective ointment.
2. Unit protective equipment, which includes sound gas-alarm, spray detectors, ground detectors, and protective boots and clothing.

Spray detectors are indicators painted with detector paint, and when spray falls on them they turn red. Ground detectors fulfil the same purpose. The scale of clothing depends on the nature of the unit, but the heavy protective equipment, which gives full protection for a considerable time, is very hampering owing to its weight, and much reduces the amount of work that can be done by its wearer. If a man finds himself severely splashed with mustard, the only salvation is to throw all his clothes off at once. Although this may be an embarrassing thing to do in public, it is better than severe mustard burns. Moreover, if done quickly, the underclothing may be retained or blankets may be borrowed. Ordnance carries several lorry-loads of spare clothing with the division.

Under conditions of protracted defence it is important that all shelters should be gas-proof. If the enemy is using gas—particularly blister gas—it is essential that the troops should be well trained in decontamination duties. Gas can be got rid of in three ways: by removal, by destruction, and by sealing.

It must be remembered that the main properties of mustard are its persistency and its great power of penetration. If removed, it may be a nuisance elsewhere. For example, if a hose is used in a city to get gas off the streets, it finds its way into the sewers and the men working in the sewers may get infected. It takes some two years for water to 'kill' mustard. A possibility is to remove it by a non-inflammable solvent, and carbon tetrachloride, which is the filling of many fire extinguishers, suits for this, but even then the disposal of the solvent must be watched.

Destruction is a good way of disposal, but is not without its dangers. If mustard is burnt, a highly poisonous black smoke is produced. If mustard is boiled, a chemical change is caused and it breaks up into two main substances, one of which is hydrochloric acid. The other constituent smells of mustard, but is actually harmless. Chlorine has the greatest effect in destroying mustard and is contained in bleaching powder. The powder is normally mixed with three parts of earth in order to quieten down the action.

Sealing is effected by earth, sawdust, ashes, &c., either by itself, or better still, mixed with bleaching powder. If mixed with the latter, a layer 2 in. thick will do, but if earth is used alone, 3 in. thickness is required. By sealing, no mustard is destroyed and the ground must be marked as contaminated.

Decontamination of clothing is an important matter if blister gas has been used. Cotton clothing can be boiled, using soda and plenty of water to dilute any hydrochloric acid that the mustard produces. Woollen clothing shrinks seriously when boiled, and this method should not be tried. The protective clothing can be boiled without damage being caused. There is no known method whereby leather may be decontaminated with success.

The present position as regards gas warfare is that most of the nations of the world have signed the Geneva Gas Protocol of 1925, in which the use of gas in war is prohibited. Japan and U.S.A. did not sign, but Germany did and so did Italy, although the latter nation made full use of it against the Abyssinians, and the present war has illustrated that the rules of warfare are regarded by the Nazis as only to be observed if it serves their purpose to do so. The British, however, having signed the Protocol, have assumed that it will be observed, and no training in offensive gas measures is to be undertaken until and unless it is used by the enemy. This will involve a great time-lag before effective use can be made of this weapon, and meanwhile training in passive defence must be good. The civilian population has been fully warned of the possibility of gas, and everyone has a mask which is fully effective against the type of concentration that the civilian is likely to meet. The soldier is given a much better mask, as he may have to face up to gas. The general ideas as regards the gas danger vary—a well-known K.C., who ought to have known better, announced some years ago that a walnut-sized bomb dropped in Piccadilly Circus would kill everyone within an 8-mile radius! On the other hand, a well-known medical expert declared that in a gas attack the right thing to do was to get into a hot bath, smoke a pipe, and roar with laughter! Neither of these two distinguished men was very fortunate in his proposal, but the medico was less incorrect than the lawyer.

For well-trained and well-disciplined troops gas is a nuisance rather than a danger, though it is not possible altogether to guard against the effects of blister gas. Furthermore, gas does not force men from a position, as casualties will only occur 24 hours later. In fact, a commander who is holding a position in a gas attack has to decide whether it is worth while to sacrifice the whole of his command 24 hours later, for the sake of the casualties that his men can inflict at the time.

In open warfare there is not much likelihood of the use of gas as a surprise. A large amount of gas ammunition is required to produce any effect; the carriage of gas complicates supply, and, moreover, if an enemy is dosed with blister gas and then retires, the same gas may inflict casualties as the attacking troops follow up. Furthermore, gas is dependent on wind and weather and cannot therefore be relied upon to produce quick and certain results.

With gas bombs from the air the concentration obtained is almost inevitably less than what was achieved in the war of 1914–18 by the use of Livens projector drums and Stokes mortars. The contents of an aeroplane bomb containing 1,000 lb. of gas only equal the contents of thirty-four projector drums, whereas these used to be discharged in hundreds in one direction. Aircraft cannot hope to drop more than one, or at the most two bombs simultaneously on one small area. It is, indeed, open to question whether the casualties sustained by a large gas bomb would be equal to those caused by an equal weight of high explosive, and as far as moral effect is concerned high explosive is even more terrifying.

It was Alfred Tennyson, in a poem 'Locksley Hall', written some ninety years ago, who envisaged the possibility of aircraft spray in the war of the future:

For I dipt into the future far as human eye could see
Saw the Vision of the World and all the wonder that would be,
Saw the heavens fill with commerce, argosies of magic sails,
Pilots of the purple twilight, dropping down with costly bales;
Heard the heavens fill with shouting, and there rained a ghastly dew
From the nations' airy navies grappling in the central blue.

CHAPTER X

THE WORK OF THE AIR FORCE COMPONENT

Any account of the mechanical and scientific work of the army to-day would be quite incomplete without some mention of the Air Force Component, as the portion of the Royal Air Force allotted to the army is called.

In the Royal Navy the attachment of R.A.F. personnel has never been so unqualified a success, and no long time ago the Senior Service was definitely given its own air management as a specific naval responsibility. The bond between army and R.A.F. has always been of the closest and so drastic a step has never been so necessary. There has, in fact, never been a serious demand in the army for its own air-arm detached from the R.A.F. outside the tactical domain. Military commanders fully realize the vital importance of maintaining flexibility in an arm which is so powerful and so mobile. In war the air force contingent allotted to the army normally includes bomber, fighter, and army-co-operation squadrons, and in many circumstances bomber–transport squadrons and kite balloons as well. Aircraft is often available as well for communication purposes. The autogyro type of machine is particularly useful for reconnaissance purposes under many conditions. These machines are slow and may require protection, but they can take off and land in a very small space—a big advantage in enclosed country.

The air component is under the direct command of the military commander-in-chief, and the R.A.F. commander is attached to the staff at general head-quarters, being responsible for the means employed in carrying out the tasks allotted to him.

The chief military characteristics of aircraft are their powers of manœuvre and penetration. They can approach objectives within their range from almost any direction and from any height up to the limit of their ceiling. Aircraft can evade each other in the air so easily that their defensive value is small, and as weapons they are primarily offensive.

Owing to their power of operating in a short period of time against widely separated objectives, they can vary their methods of approach to such an extent that their employment offers wide scope for surprise, so that they can achieve moral effect out of proportion to their actual strength.

It is not always appreciated how much aircraft depends on an efficient ground organization for its maintenance. At the outbreak of war in September 1939 it was often asked why the R.A.F. was not able to do more in support of the sorely stricken Polish air force. It would have been quite feasible for British aircraft to have flown across to Poland, but, no land route being available, the ground organization was unable to make the journey. Moreover, aircraft are very vulnerable to both ground and air attack when at rest. The Germans quickly realized this when they treacherously attacked in the early hours of 1st September without any previous declaration of war, and repeated assaults were made on the Polish aerodromes, which crippled their air force almost from the start. Aircraft soon lose efficiency if their aerodromes are changed too frequently or if they are required to operate for any long period from an advanced landing-ground, separated from both workshops and stores.

Bomber aircraft vary in class from the single-engined type with a light load and high performance to the multi-engined variety with a heavy load and moderate performance. The former is mainly intended for day bombing and for finding out all about the enemy dispositions in relatively remote districts. The latter type is equipped with more considerable navigation facilities and is intended for work at night. Owing to its larger size it can carry a greater armament. Certain classes of twin-engined bombers are suitable for work by day or by night, but for distant objectives a smaller bomb-load is alone permissible, owing to the greater weight of fuel that is necessary. The types of bombs used are heavyweight high-explosive bombs designed for penetration and useful on such a target as a battleship; general purposes heavy, medium, and light-weight bombs, and small incendiary bombs. Within limits the load can be made up of a combination of these.

Bomber aircraft normally carry two-way wireless telegraphy for communication with the ground. Front and rear guns are fitted to these for particular purposes, but at the speeds attained nowadays, the machine gunners of the multi-seater machine are confronted with many difficulties. The pursuit plane pilot follows his enemy and sprays him with machine-gun bullets, being to some extent protected in his cockpit by his own engine.

In aircraft work, constant and continuous research is necessary towards the perfection and improvement of the various types. Variable-pitch propellers, which perform the same function in aircraft as a gear-box in a motor-car; retractable undercarriages, which reduce wind resistance; flaps, which reduce landing-speed; and slots, which provide safety at low speed—are all examples of the fruits of fairly recent research. Much of this research has been the product of the gliding enthusiast, and Britain has recently woken up to the necessity of doing more to make her citizens air-minded. The social, pleasurable, and recreational side fades out altogether in time of war, but the aircraft industry may well take an example from the private motor-car and the fillip that it has long given to the automobile industry.

Fighter aircraft are characterized by high speed, high ceiling, quick climb, and snappy movements. Some of these aircraft are single-seaters and others are two-seaters. The single-seater type has the highest performance and is perhaps the more important. At the speed of the modern fighter there is difficulty in training a gun, and the pilot shoots in the direction in which he is pointing. It is much easier to keep an aeroplane with a fixed machine gun well aimed on its object than it is to manipulate an independent machine gun, subject to more or less violent wind-pressure. In the case of the former, precision is very great, attacks on long supply columns being particularly effective. The two-seater is more suited for offensive action against large formations owing to the existence of a rear gun. Fighter aircraft required for night fighting are fitted with night-fighting gear, and wing-tip flares. A fighter aircraft is capable of carrying a small load of light bombs which is useful in low-flying attacks on ground targets.

Aerial battles usually involve organized bodies, and the isolated aerial duel is not so likely. Generally speaking, two formations of fighters come to grips in the first phase—one protecting its bombers, the other trying to turn the big aircraft from their mission. If the protecting fighters are beaten, it is all over with the multi-seaters, and they will have great difficulty in regaining their bases without registering heavy losses. Many fighters are required to protect a flight of bombers, and the Germans have found to their cost the dangers involved when bombers travel distances which are such that escorts of fighters must perforce be left behind.

The army co-operation aircraft demand very highly trained personnel owing to the variety of duties with which they are entrusted. Their work includes air photography, 'spotting' for the gunners, close and medium reconnaissance. For these purposes the aircraft in use must have handiness of control, a clear all-round view and especially downwards, and ability to operate from restricted landing-grounds. The machines are invariably two-seaters, and of these two the pilot, who is an officer, is responsible both for making the observations and, except when using the army wireless telegraphy, for transmitting the reports by the method of communication that the particular task demands. The other seat is occupied by the air gunner. His duties are solely protective. He usually has a front and a rear gun, and the machine often carries a moderate load of light bombs for use in case a tempting target for low-flying attack is offered. The performance required of an army co-operation aircraft is not unlike that of the lighter type of single-engined bomber.

Aircraft for transporting troops are exactly similar in type to the large twin-engined bombers, their fuselage being, of course, specially constructed for the purpose of carrying passengers and some cargo. In view of the fact that it is possible to adapt them for bombing, squadrons of these machines are termed bomber-transport squadrons to indicate their dual purpose. It must be realized that troops may suffer considerably from air sickness during a long journey, thus impairing their fighting value immediately after arrival.

Kite balloons constitute the remaining component of the Air Force component. They can carry out observations up to a height of 5,000 ft., the observer being in telephonic communication with the ground. Owing to their vulnerability the observer has to operate at long range, and high magnification glasses or telescopes are essential. The kite balloon should normally be protected by anti-aircraft fire from the ground. If close attack by enemy aircraft becomes frequent, it is possible to arrange for a dummy balloon containing a large amount of high explosive to be hoisted; the detonation of this should destroy the attacker, and the possibility of such a device being used is particularly damaging to enemy morale.

The gaining and maintenance of air superiority is of first importance. It enables the army to dominate the enemy by its knowledge of his movements, and by denying him such information. At the same time no amount of superiority in the air will enable the enemy aircraft to be kept entirely over his own ground.

By day, bombing is normally carried out by formations, bombs being released upon a signal from the leader. Sustained bombardment entails attack at intervals, and such attacks have the greatest moral effect. Mass attacks are delivered by large concentrations of aircraft and are employed when material rather than moral damage is desired. Night attacks are normally carried out by single aircraft arriving over the objective at irregular intervals, it being inadvisable to have more than one aircraft over the objective at once, and time is taken to adjust sights and to drop bombs. This does not apply to mass attacks on a city like Warsaw or London. Bomber formations by day take photographs immediately after their attack, to reveal, if possible, the extent of the damage caused.

The principle of concentration is of special importance in bombing attacks. Constant and continued bombing against a primary objective selected by the military command must be the policy, with no diversion to secondary objectives.

The target to be attacked may be enemy aerodromes, vital points in communications such as railway bridges, harbours, supply centres, or head-quarters. Air photography will assist in deciding on the objective. Railway bridges offer small targets, and are not easily destroyed except with the heaviest bombs.

Low-flying attack refers to attack by fighter aircraft from a low altitude, usually at very high speed, machine guns and small bombs being used. The moral effect of this manner of attack may be great, but against well-trained and well-equipped troops such attacks are likely to be unduly costly. The little German pom-poms fire 200 shots a minute, so that a battery of six can create a veritable barrage of twenty shells a second. Our own aircraft attacking Kiel and Heligoland found that very concentrated barrages were directed at them.

The best results from low-flying attack are likely to be obtained in the pursuit. In such circumstances enemy morale is likely to be poor, and effective low-flying attack may turn an orderly withdrawal into a rout. The air attack on the Turks in the Palestine campaign supplies a good example of this. Moreover, owing to the probable absence of organized anti-aircraft fire at the time, casualties to aircraft are likely to be small.

Aeroplanes can also act as long-range artillery. When guns are scarce, aircraft may be used instead. Such bombardment is as efficacious morally as it is lacking in precision materially.

A subsidiary but important use of aircraft is for photography on behalf of the army survey services. In some theatres of war the army may be entirely dependent on maps produced in this manner. But photographs obtained for ordinary reconnaissance are unsuitable for survey purposes. Survey photographs must be taken under exacting conditions as regards height, tilt of camera, and overlap.

The amount of work that an army co-operation squadron can do depends on a number of factors. It is conveniently measured in terms of 'sorties'. This word implies the performance of one task by one aircraft whatever the nature of the reconnaissance. A sortie involves approximately two hours' flying over the enemy lines, and a squadron can be expected to carry out an average of twelve sorties each day. Such a squadron may be allotted on the scale of one per division, though usually remaining under corps control.

For reconnaissance purposes there are two main types of air photography—vertical and oblique. Both can be used stereoscopically to show relief, and the former can be made up into mosaics to include large areas of country. Oblique photographs are of value in indicating the nature of the country, a line of advance, and, in conjunction with a map, the identification of features. This necessitates flying at low heights, possibly within range of the enemy small-arms anti-aircraft fire. A single aircraft is able to photograph an area of 12 square miles on a scale of 1/10,000 with an adequate overlap, provided that two hours' uninterrupted flying at a height of 8,000 ft. over the area is possible. The whole area would be covered by approximately 100 overlapping photographs, and the squadron photographic section could carry out the developing and printing in a very few hours if conditions were favourable.

These few examples show in how many ways the air force can assist the army, and in return the army holds the bases, the aerodromes, and the advanced landing-grounds of the air force. Other possibilities include demolitions or even the formation of a bridge-head to secure the passage of a river, parachutes being used and supply being maintained by air. Concentration, economy of fuel, mobility, co-operation, and surprise are all aspects of the flexibility which aircraft can help so much to preserve, and for which it is so important that the army and the R.A.F. should work together with the utmost harmony.

CHAPTER XI

CONCLUSION

A FEW examples have now been given of the application of science to land warfare—no attempt has been made at completeness, but it has been shown that applied science and mechanization play a part in the work of every branch of the modern army.

It is sometimes argued that the soldier lags behind civil practice in his use of science, and examples can often be given in support of this. It is not altogether realized how cautious the army has to be in its adoption of any innovation. Until the rearmament campaign was instituted the army was given very little money wherewith to conduct research in any direction. Moreover, however promising technical development may be in any one direction, it must be remembered that to equip the army with any particular weapon costs an enormous sum, and once an article of equipment is adopted, no change is possible for many years. The degree of robustness of a weapon that has to face up to war conditions is, moreover, very great. Soon after the war of 1914–18 a great many experiments with an amphibious tank were carried out both here and elsewhere and with a good deal of promise, but now, over twenty years after, no army can claim a fully satisfactory solution. Standardization is far more important than the layman imagines, and the army has often to be content with less efficient equipment if the advantages of standardization in war-time production are to be attained.

Furthermore, any new equipment makes all previous material obsolete, and it is a serious drawback in war that the reservist, of whom all mobilized armies are in the first instance mainly composed, will not understand its use. In the present war the armies of all belligerents must have experienced this difficulty at the outset.

The fundamental principles in modern scientific discovery are often relatively simple, but it is the practical details that are so important and so difficult. Television is a good example of this. To send a picture over a single communication channel it must be broken up in exactly the same way that a printed line can be broken up into its letters. This process is called 'scanning' and was invented over fifty years ago. Even the photo-electric cell, which turns light variations into electric variations and which is so important in modern research, dates back to 1875. Then comes the cathode-ray tube, which builds up the received picture by varying the strength of a moving beam of electrons, and this was discovered in 1897. So that the basic principles of television are in no way new, but many experiments were required for their development. It is the speed of millions per second at which variations of light intensity must follow each other that complicates the work, and without the improvement in amplification by valves that has taken place, to do this alone would be impossible.

The method of focusing such electrons on a small spot on a screen is another problem and required the development of electron lenses. Even then the transmission would be impossible on medium wave-lengths as it would require too much space in that very part of the ether which is already overcrowded. With all these complications to be overcome, it can readily be seen how impossible television would be under war conditions, when the enemy is doing his best to interfere with the work.

Photo-telegraphy sounds an attractive way for an aviator to transmit to his comrades a description of the enemy's dispositions, but it is not yet in the sphere of practical politics. Noctovision is not so unlikely, as the complications are fewer. In noctovision, infra-red rays, which are invisible, are projected from a light source screened by a frame that lets pass only the invisible but highly penetrating 'black light' or infra-red rays. Searchlights equipped with infra-red projectors have been tried with some success, and the beam is, of course, quite invisible. Soldiers creeping up to make a night attack could have their movements invisibly and unconsciously 'noctovised' by the defenders. Such infra-red rays have a range of some 25 miles and use lenses not unlike an ordinary searchlight. But here again practical details are likely to prevent the application of such attractive possibilities under the humdrum conditions of the modern battlefield.

So that the scientist who revolutionizes warfare belongs to the sensational novel rather than to the world of everyday realism, but this is not to say that he is not wanted in the modern army. In all branches the technologist and the scientist are of the greatest importance, and one of the advantages that compulsory service has given is to increase the army's intake of tradesmen. They are wanted in all arms and in all branches. In the infantry a large proportion of motor-drivers and mechanics are required to look after the Bren carriers and the large number of vehicles that are included in the battalion. Moreover, armourers are wanted far more than in the days when the rifle was the main weapon.

Nearly all the cavalry regiments of the army are included in the Royal Armoured Corps in which the Royal Tank Regiment is incorporated, and the Royal Tank Regiment training-school at Bovington is well known for its up-to-date methods for training its technical troops.

The Royal Artillery requires a large number of mechanics, surveyors, and meteorologists, and in the Royal Engineers the number of tradesmen of all kinds is such that a large percentage of its regular army intake receives early training as boys at Chepstow and at other training-schools before joining the corps.

The Royal Corps of Signals trains a number of electricians as well as mechanics, and the Royal Army Service Corps is responsible for the army transport in general, and all its intake on the transport side requires technical knowledge in various directions.

The Army Ordnance Corps is responsible for the army's heavy machinery, and large base workshops work under its control.

Plate 23 gives a slight idea of the activities of the modern army in time of peace, and shows how the soldier is trained as a boy when he joins, and at a vocational training centre which is intended to fit him for civil life after his service.

In time of war the system is naturally less leisurely, and more regard must be paid to the necessity of getting efficient service in the shortest time, but it is then more necessary than ever that the training of both officers and men should be thorough and efficient. In war it is the side that makes the least mistakes that wins, and a combination of up-to-date thought and the time-honoured moral qualities is required more than ever by the young leader at the present time. Reports all agree that in the German military colleges the poor intellectual standard involves a lack of clear thinking and an ineradicable tendency to use catch-phrases.

In order to have the confidence of his men a leader must have confidence in himself. He must be able to make up his mind, and having done so, he must stick to his decision. To show doubt and indecision is the most certain way of losing the confidence of his men. Loyalty is essential to leadership: unless a man is himself loyal to his superiors, he cannot expect loyal support from his subordinates. Finally, he must appreciate the importance of keeping cheerful and encouraging his men to make the most of adverse conditions. It is always encouraging to feel that, although things may seem to be going none too well, they may be even worse with the enemy. If it is felt that mistakes have been made, an admirable antidote is to read Ludendorff's *Memoirs*, which will show how serious were those made by the Germans in the war of 1914–18.

It is now the considered policy of the British War Office that all future army leaders must share the common companionship of the barrack-room. Apart from specialist appointments, all commissions are being given from the ranks. All young men joining the army have, therefore, equal chances of promotion, and advancement is entirely dependent on merit; the star is within the reach of every private soldier. It is, above all, important to gain whole-hearted service from the young, with whom ideals of freedom and justice count for more than material interests. The approach to our problems must be in the scientific spirit, in which the predominant interest is to discover the truth, and this atmosphere can only be attained if liberal civilization survives—and it is for this that war was declared against Germany in September 1939.

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